

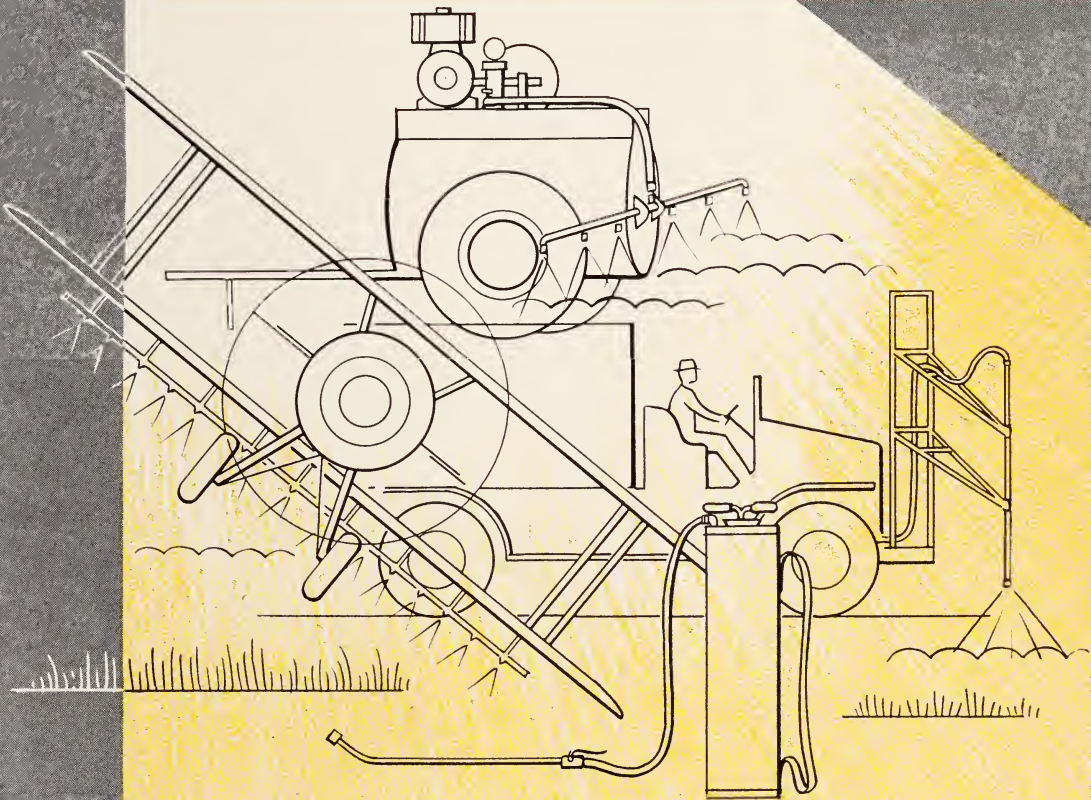
CALIFORNIA AGRICULTURAL EXPERIMENT STATION

CIRCULAR 389

DECEMBER 1948

CHEMICAL *Weed-Control* EQUIPMENT

NORMAN B. AKESSON and W. A. HARVEY



THE COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA • BERKELEY

This circular is a handbook of weed spraying equipment. It describes types of sprayers, tells how to select the right one for a specific job, gives suggestions for building a spray rig, and includes a section on calibration.

The information is intended mainly for the farmer, to help him buy, hire, or build weed-control equipment. It should also be of interest to manufacturers of equipment because it indicates desirable design features and describes new methods which are proving successful.

Specific weed-control problems are not discussed here. They have been treated in a series of publications which are available from the College of Agriculture.

CHEMICAL WEED-CONTROL EQUIPMENT

Norman B. Akesson and W. A. Harvey

CHEMICALS have been used for controlling weeds in California for many years. Their use has proven so practical that they are replacing cultivation as a control measure in many orchards, vineyards, and row crops. Normal farming practice now includes chemical treatment of barley, wheat, rice, milo, carrots, celery, corn, and other crops. Chemicals are also used on fence rows, roadsides, and ditchbanks, for control of weed growth.

Many varieties of herbicides which may be applied as sprays or dusts are available to the farmer to help him solve his weed problems.

Equipment for applying these chemicals includes: hand sprayers; motorized ground rigs; airplanes and helicopters; and ground dusters.

Before the farmer chooses equipment for weed control, he should take into consideration the following important factors:

1. The varieties of jobs the equipment will have to do. This, of course, depends upon the kinds of weeds to be controlled, and the crops in which they occur. For example, if the spray equipment must be adaptable to high-pressure orchard spraying and cattle spraying, as well as to weed control, it would be advisable to choose a high-pressure sprayer which can be regulated to lower pressures.

2. The total area to be sprayed. This determines, to some extent, the cost. It may be cheaper to hire a commercial outfit to do the spraying, or it may be economical for the farmer to build his own rig. If large acreages are to be sprayed with high volumes, it may even be practical to have several medium-sized rigs instead of one very large one.

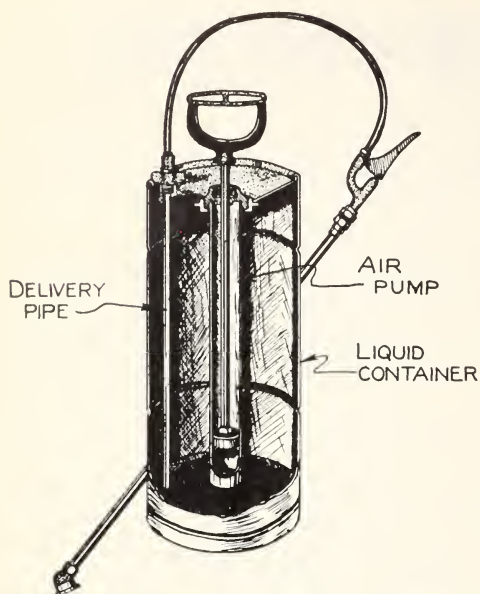
Abbreviations used in this circular

rpm	revolutions per minute
psi	pounds per square inch
gpm	gallons per minute
gph	gallons per hour
mph	miles per hour

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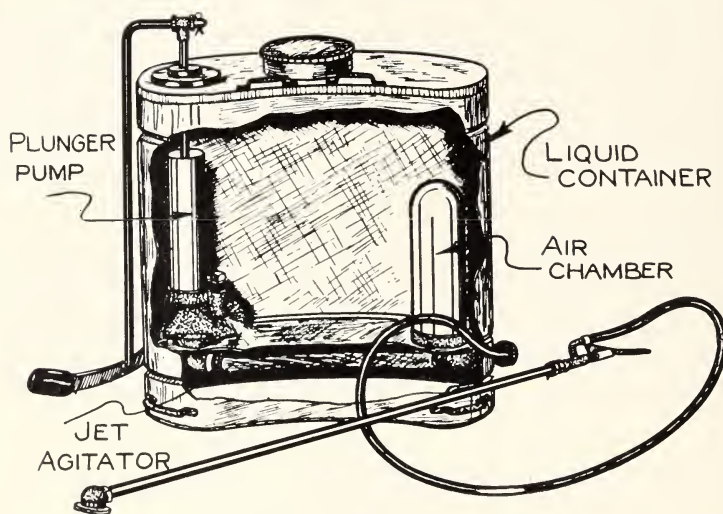
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Small Portable Sprayers...



Knapsack sprayer with a compressed-air pump. A simple air-displacement pump is mounted inside a small (3- to 4-gallon) cylindrical tank. Hand-pumping compresses the air in the tank to 50 to 75 psi (pounds per square inch). The air pressure forces the liquid out of the spray nozzle if the discharge valve is opened. Frequent stops must be made to pump up the pressure, which drops as the liquid is forced out.

NOTE: Compressed-air sprayers are suitable for small lawns and gardens. It is best to keep one of these sprayers for weed sprays only, and not try to clean it for use with insecticides or fungicides.

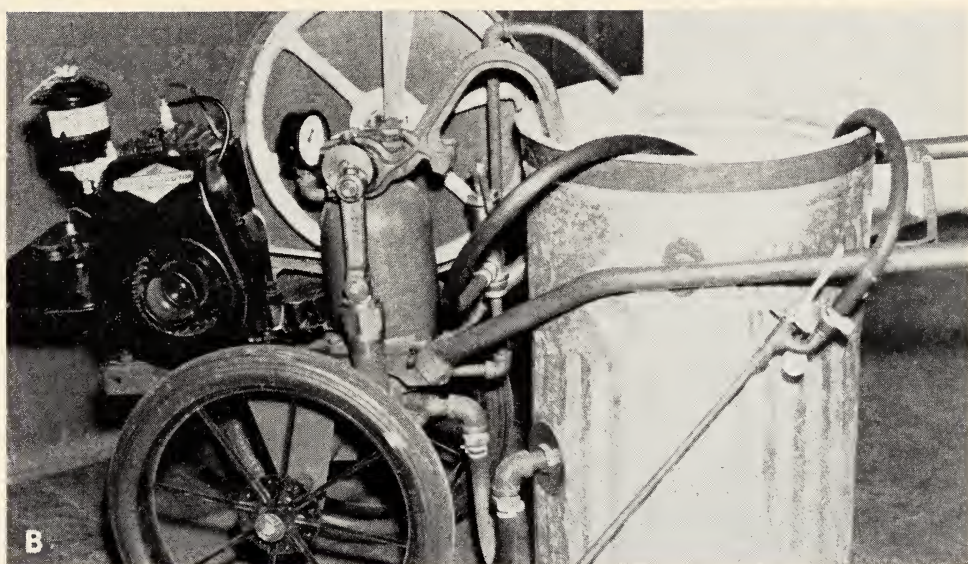
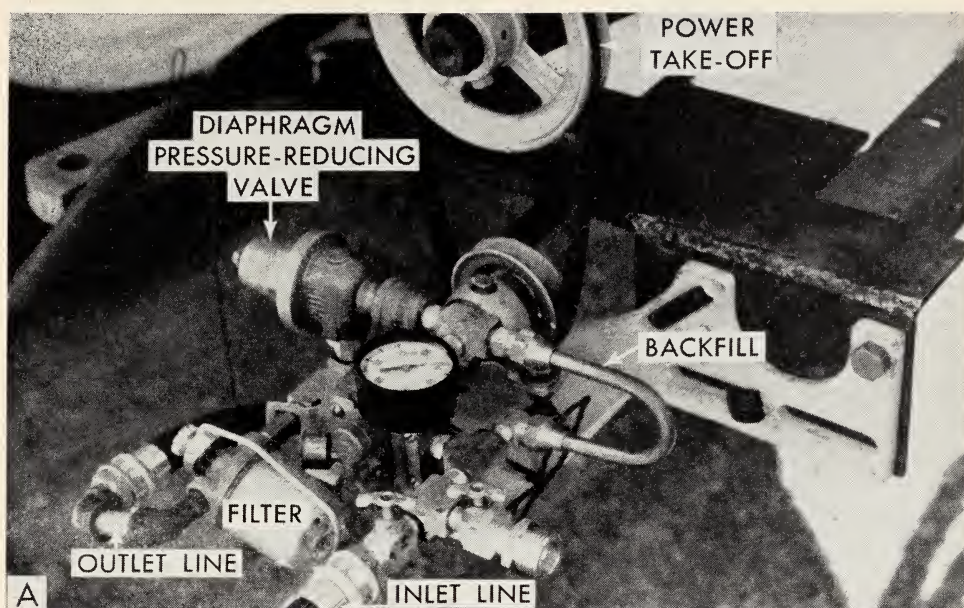


Constant-pressure knapsack sprayer with a plunger pump. Similar sprayers are also available equipped with diaphragm pumps. The pump is fitted with a small air chamber which maintains uniform pressure (50 psi or more) regardless of the amount of liquid in the tank. Since the tank merely supplies liquid and does not have to withstand pressure, it may

carry the pump either on the outside or built in. This sprayer requires continuous hand pumping.

NOTE: Hand-operated sprayers with a larger capacity than the knapsack types are also available. They may be mounted on a 2-wheel cart or wheelbarrow frame for easy moving.

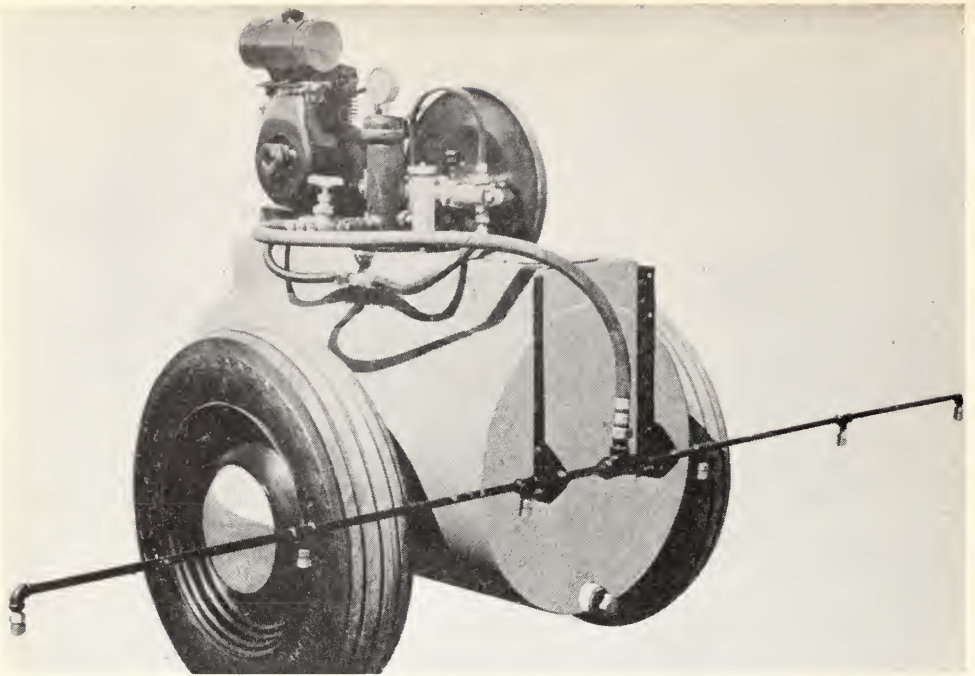
Small Power Sprayers . . .



Small power sprayers: *A*, mounted on small tractor; *B*, mounted on wheelbarrow frame. These sprayers are for use on a comparatively small area, but one which is too big for coverage by a hand sprayer. Any small pump and engine unit which will discharge 2 to 4 gpm (gallons per minute) at 50 to 75 psi will be satis-

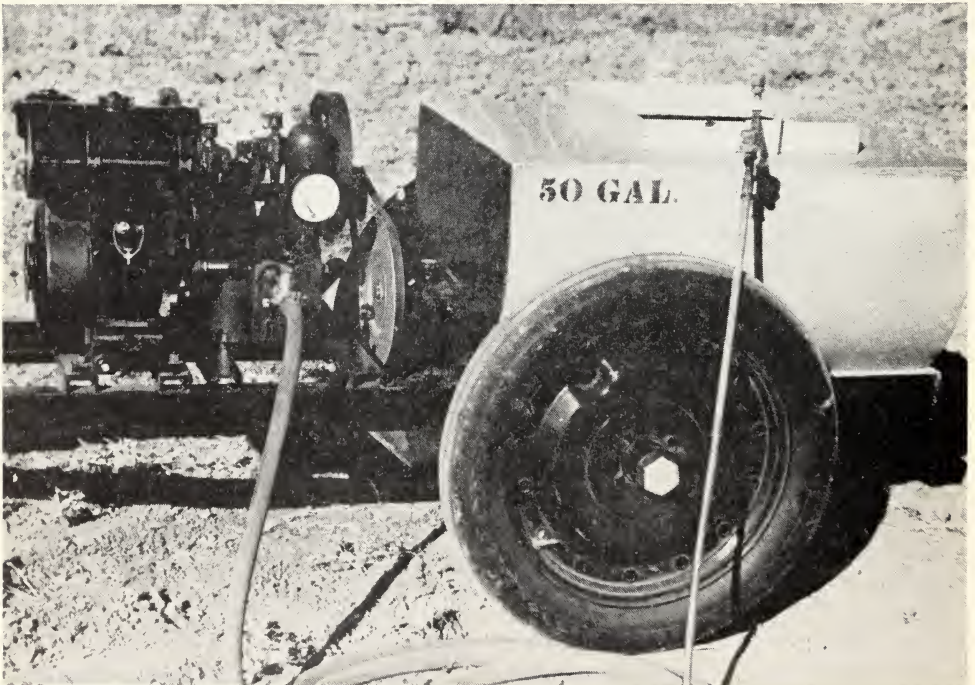
factory for general weed spraying. It will carry a hand boom or gun of 2 or 3 nozzles.

NOTE: Units which combine low volume (2 to 4 gpm) and low pressure (20 to 50 psi) may be used only with such low-volume sprays as 2,4-D. All other spray materials require higher volumes and pressures than these pumps will handle.



These small "estate" sprayers are intended primarily for orchard and cattle spraying, and therefore operate at higher pressures than are necessary for weed

spraying. However, the pressures may be reduced for weed spraying if desired, using either a hand boom (below) or a short field boom (above).



Pumps...

The most important item to be considered when choosing a power sprayer is the pump. Where one piece of spraying equipment is to be used for several different jobs, such as orchard, cattle, and weed spraying, a high-pressure pump is practical. The pressure may be lowered for weed spraying with the by-pass valve

or pressure regulator. If the equipment is to be used for weed spraying only, a high-pressure pump is not necessary, since a maximum nozzle pressure of 75 to 125 psi is adequate. Nor would such a pump be practical, because its initial cost for a given capacity is two or three times that of a low-pressure pump.

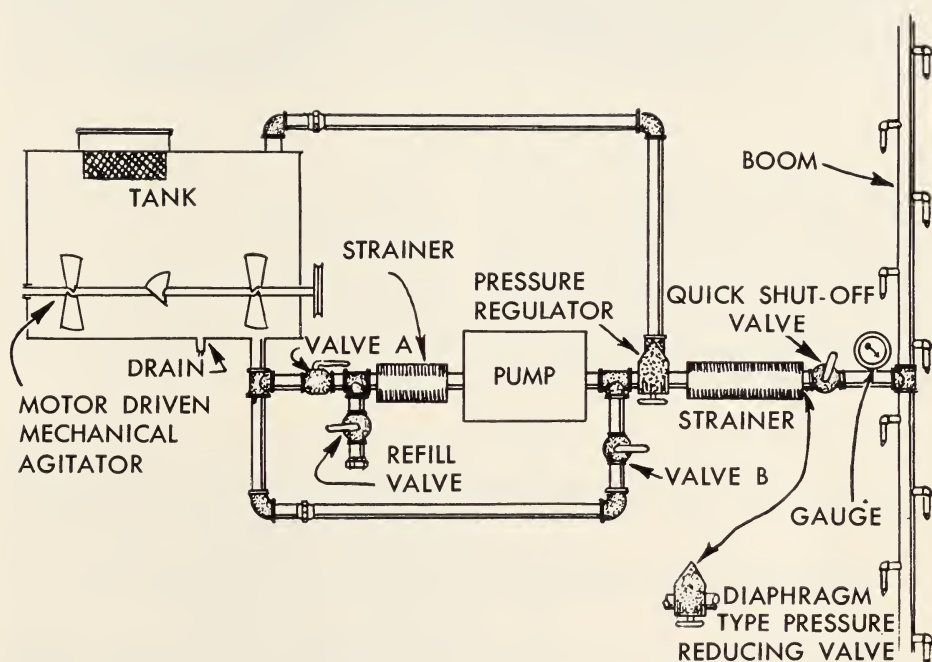
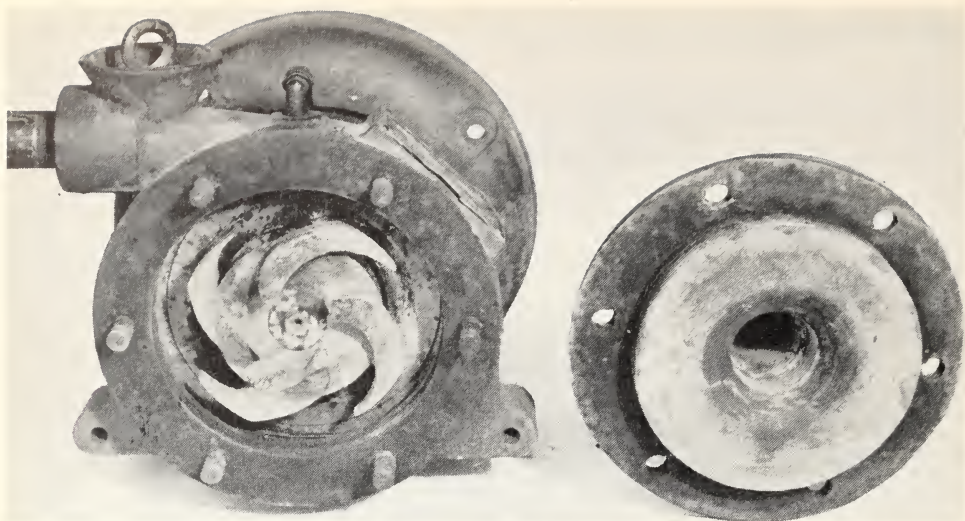


Diagram of a weed sprayer using a positive displacement pump. Plunger and gear, and certain types of rotary pumps, are positive displacement types, and do not need priming. They do need a by-pass valve or pressure regulator to relieve the pump when the spray nozzles are shut off.

This pump has been adapted for low-pressure weed spraying by insertion of a diaphragm type reducing valve in the

boom feed line. This is necessary if the main by-pass regulator will not work below 100 psi. A by-pass regulator must always be included in the line of a positive displacement pump.

The tank is backfilled by attaching a suction hose to the refill valve, which is then opened. Valve "B" is also opened, and valve "A" is closed. This forces the liquid back into the tank.



Centrifugal pump with cover (right) removed to show impeller.

The centrifugal pump develops pressure by means of the impeller, which rotates rapidly and imparts velocity to the liquid. The speed with which the impeller moves, at its outer edge, determines the amount of pressure. For this reason, it is important to know the diameter of the

impeller (D) and its number of revolutions per minute (rpm). Pressure is in proportion to D^2 . For example, a centrifugal pump with an impeller 12 inches in diameter will develop four times as high a pressure as one with a 6-inch impeller, if they have the same rpm.

The pump capacity is determined by the maximum amount of liquid to be discharged from the nozzles. It may be figured by using the following equation:

$$\frac{\text{mph} \times \text{ft. per mile} \times \text{boom length ft.} \times \text{gals. per acre}}{\text{Sq. ft. per acre} \times \text{minutes per hour}} = \text{pump capacity}$$

For example: The discharge is to be 100 gallons per acre, at 5 mph, with a 25-foot boom:

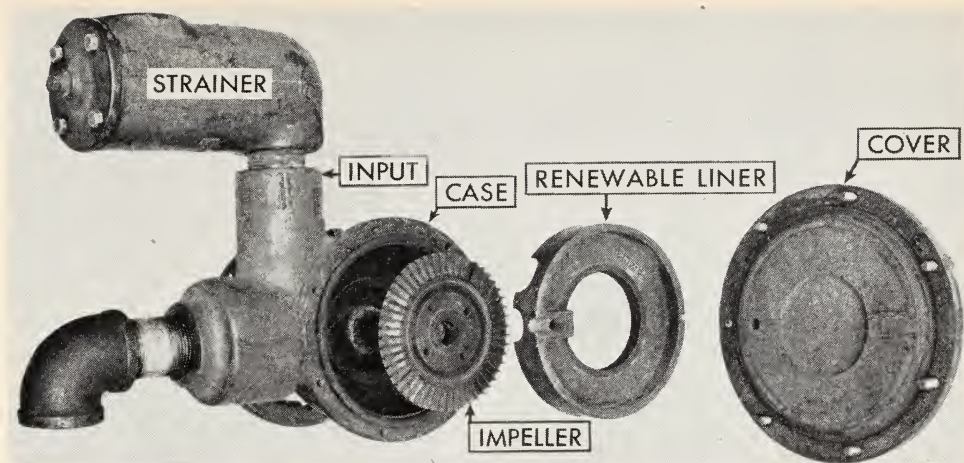
$$\frac{5 \times 5280 \times 25 \times 100}{43,560 \times 60} = 25 \text{ gpm pump capacity}$$

On the basis of this equation, there is a rough rule which may be used to determine pump capacity:

For each 100 gallons per acre, at 5 mph, the pump must supply 1 gpm per foot of boom, at the pressure to be used.

For example: If 150 gallons per acre is the maximum rate, $1\frac{1}{2}$ gpm per foot of boom is required.

NOTE: This rule is based on the maximum gallons per acre the rig will deliver unless ground speed is reduced.

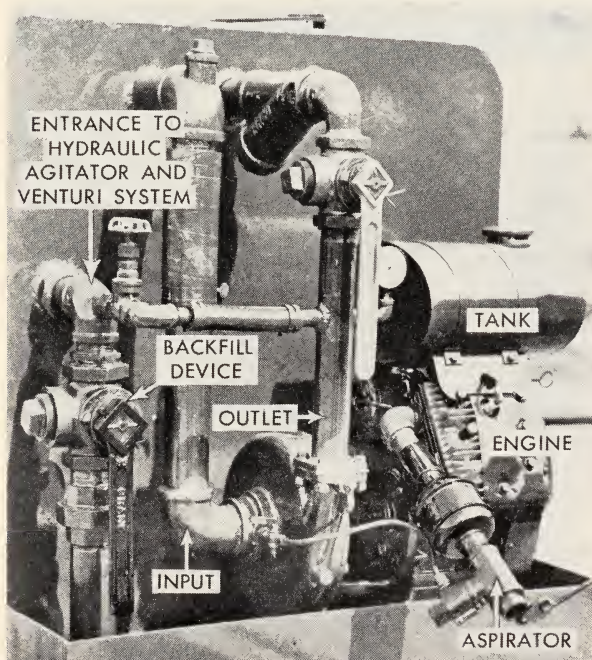


Another type of centrifugal pump is the regenerative turbine. (This should not be confused with the deep-well turbine, or diffusion-vane pump, which is also a centrifugal type.) This pump builds up more pressure than an ordinary centrifugal having the same impeller size and speed, because it has a regenerative action which throws the water outward from the blades against the case and back to the blades. This process is repeated as

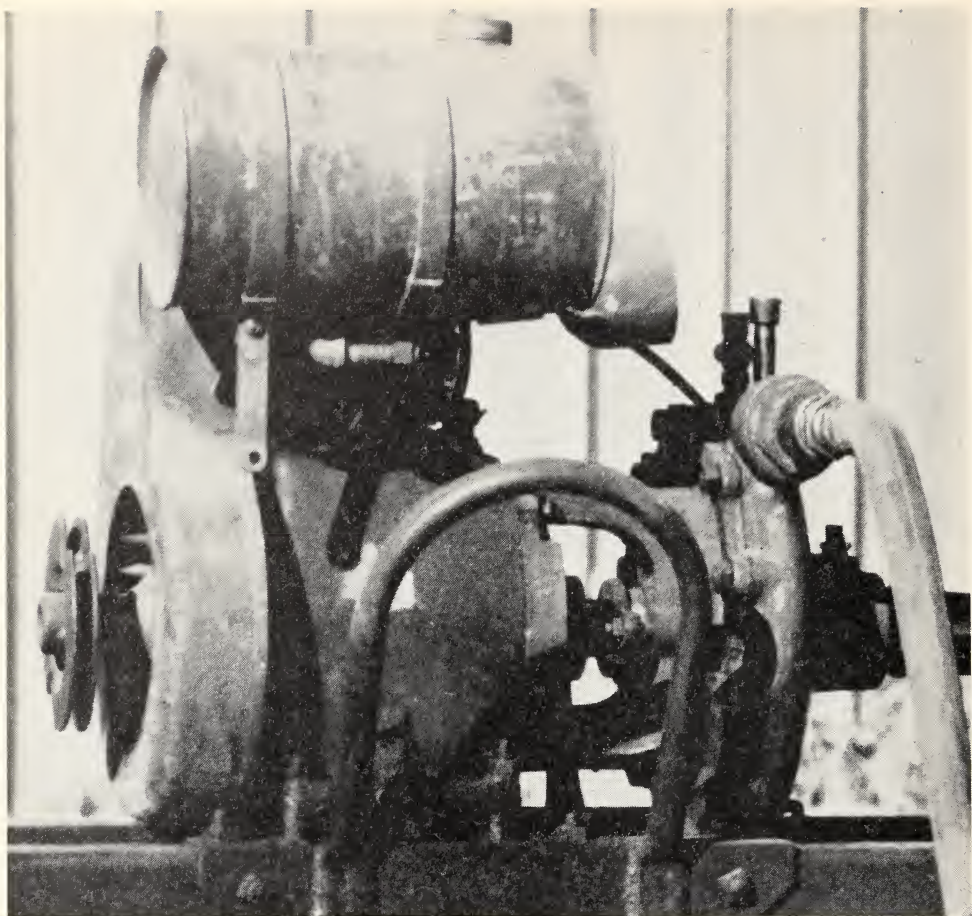
many times as necessary to bring the water to the pressure required.

Centrifugal and regenerative turbine pumps are not self-priming, although they are so called if they are equipped with priming devices, some of which are shown in the accompanying pictures.

CAUTION: The fine blades on this type of pump will wear out rapidly if abrasive or gritty particles are in the spray liquid.



This centrifugal pump, a medium-sized one, uses the exhaust from the engine, with an aspirator, to draw the priming liquid into the pump.

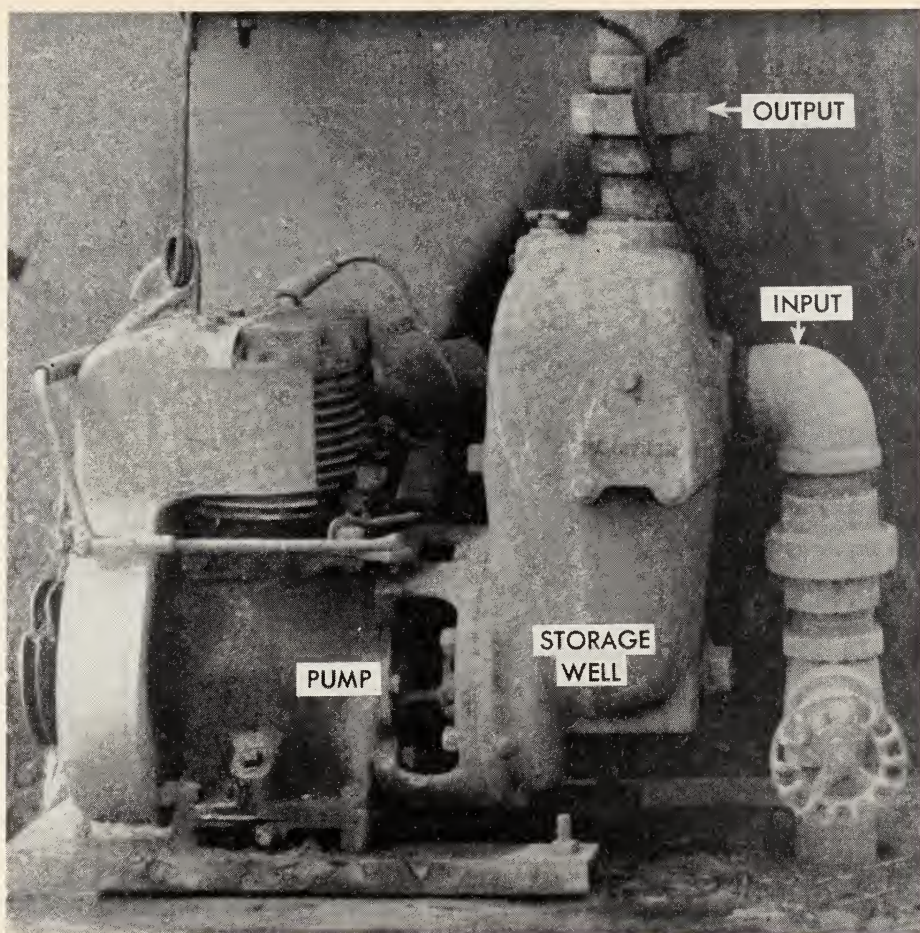


In order to produce sufficient pressure, centrifugal and turbine pumps must operate at relatively high speeds (3000 to 3600 rpm). Power for maintaining these speeds is usually supplied by a gasoline engine. Several manufacturers build moderate-sized units such as the one shown here. A single-stage centrifugal pump is attached directly to a single-cylinder, air-cooled engine.

Higher pressure can be obtained at the same pump speed or the same pres-

sure at lower speed by using a two-stage or multistage type. This consists of two or more centrifugal pumps mounted on a single shaft, in the same housing. The pumps operate in series, the discharge of the first going to the intake of the second, etc. With this type pump, speed may be regulated for high or low pressures.

NOTE: The power requirement for many centrifugal pumps is greatest at zero pressure and maximum discharge. The engine should be large enough to sup-



ply the necessary power without being overloaded. A commercially built pump and engine unit will either be designed to prevent overloading, or it will have instructions with it, showing maximum operating time at full discharge.

The pump casing shown above has a built-in well on the inlet side, for priming the pump.

A centrifugal pump for weed spraying

may also be primed (1) by mounting the pump below the water level in the supply tank, or (2) by addition of an exhaust-driven aspirator which will hold enough liquid to prime the pump.

NOTE: Neither centrifugal nor regenerative turbine pumps are positive displacement types, and no harm is done by closing the discharge while the pump is in operation.

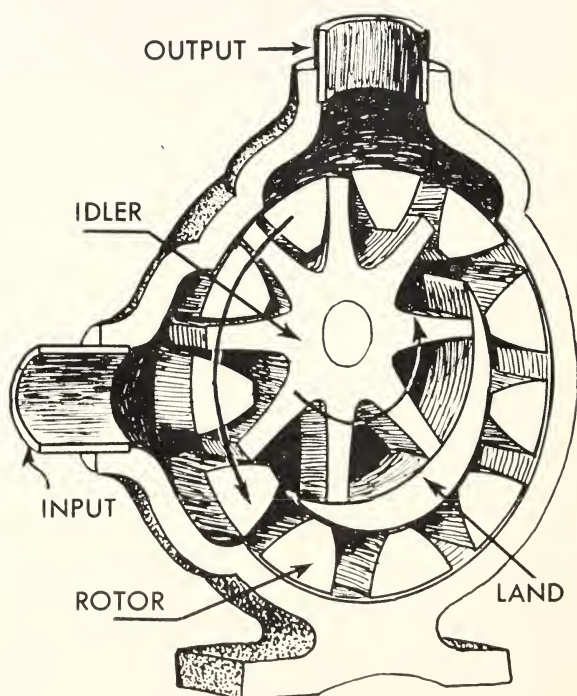
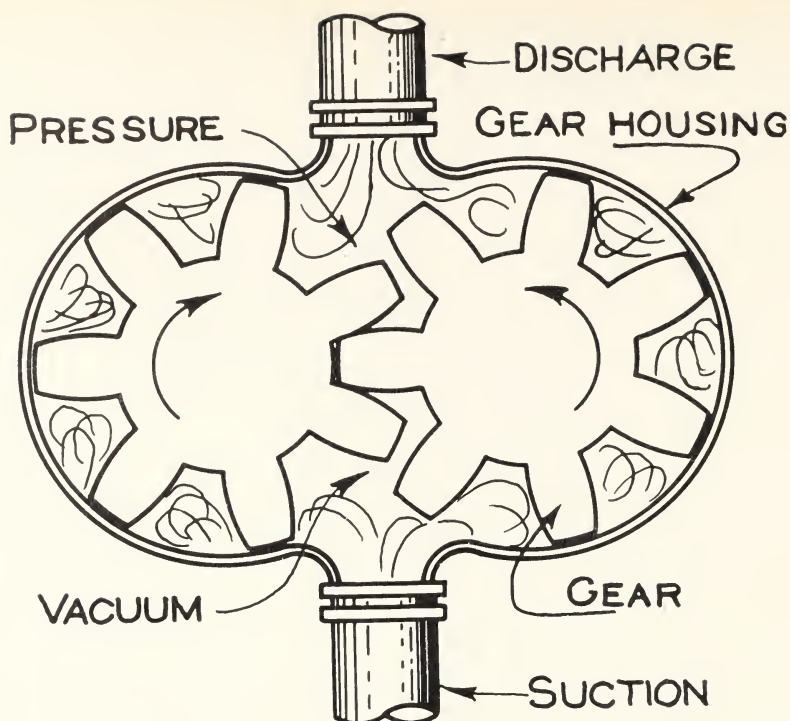
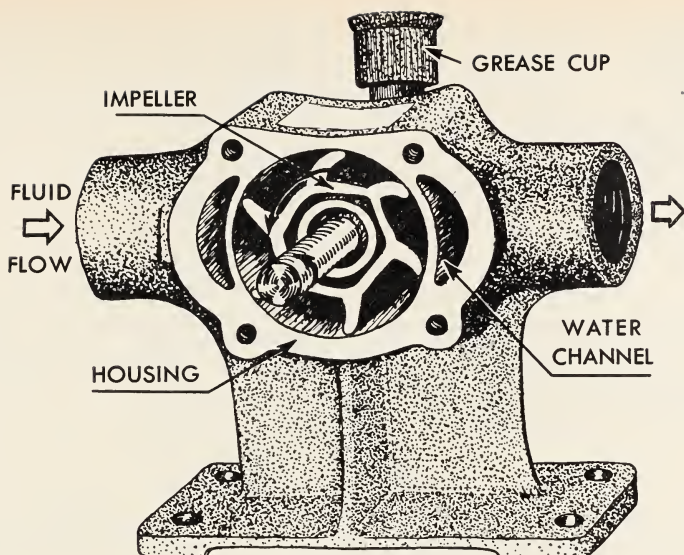
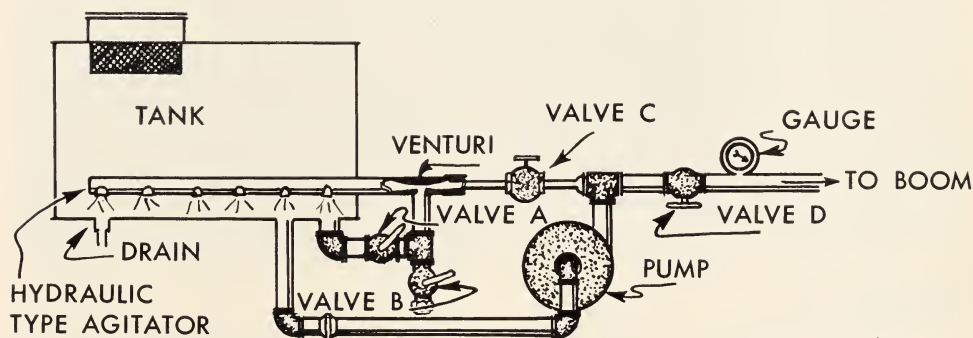


Diagram showing another type of pump used for weed spraying—the rotary gear pump. Above: Gear pump with external flow. Liquid follows the gear housing. Right: Gear pump with internal flow. Liquid enters gear system through the rotor and is forced out by the meshing of the rotor and idler.



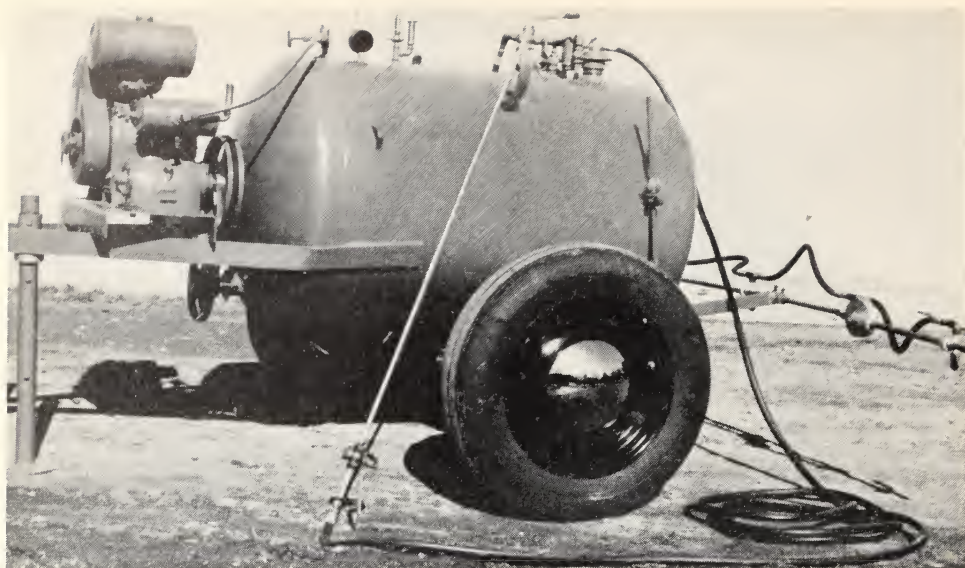
Another kind of rotary pump is equipped with flexible rubber impellers, as the diagram shows. These are becoming increasingly popular because their cost is low, and they are not damaged by abrasives in the spray liquid.

CAUTION: The rubber impellers on these pumps do not stand up well when used in sprays having a high oil content, and care must be taken never to allow this pump to run dry. The design of most types will not permit pressures of over 20 to 50 psi.



Centrifugal and turbine pumps do not require by-pass pressure regulators or relief valves. Pressure may be controlled by a diaphragm type, pressure reducing valve, or by opening the control valve, as shown in the accompanying diagram. Here, valve "D" may be a pressure

reducing valve or a simple gate valve if pump pressure is reasonably steady. This model has venturi-operated hydraulic agitation and backfill. Backfill is operated by connecting a suction hose at valve "B" and by opening valves "B" and "C" and closing valve "A."



A hydro-pneumatic sprayer such as this may be used for field weed spraying or for applying oil sprays on weeds in citrus orchards. Spray liquid is carried in a pressure-tight tank, and does not pass through a pump. A compressor forces air into the tank, and the liquid is in turn forced out through the spray nozzles. If the air compressor has an adequate filter to protect it from dust, it will stand average usage with little wear.

The sprayer shown here has a mechanical agitator, which enables the equipment to be used with all kinds of sprays. Some models provide a bubbling type of agitation by means of an air-discharge tube inside the tank, but this can only be used with mixtures which are easily kept in suspension.

Power . . .

All pumps, except the simple, hand-operated ones, are run by an engine. If the pump and engine are bought separately, it is necessary to decide first on the size of the pump. This, in turn, will depend upon the maximum discharge that will be required of the sprayer. Each type of pump will carry information showing the pressure per square inch

NOTE: This type sprayer is limited to relatively small sizes because large pressure tanks are both expensive and heavy. Large air compressors are also expensive—they cost almost as much as reciprocating high-pressure spray pumps.

Compressors are generally rated in cubic feet per minute volume at atmospheric (app. 15 psi) pressure. To convert to normal operating pressures (100 psi, for example), the relation $P_1 V_1 = P_2 V_2$ is used, where the subscript 1 denotes the pressure and volume at atmospheric (or given) conditions, and the 2 is for the pressure and volume under the required conditions. One cubic foot per minute at the desired pressure will then equal 7.5 gallons per minute discharged.

produced at various discharge rates (in gallons per minute). The engine must be large enough to run the pump at full capacity.

It is also possible to buy almost every type of pump in combination with an engine—both mounted on a single base and designed as a unit. These are very satisfactory for spray outfits and are gen-

erally made in several sizes, with various pressure and discharge rates. These rates are always included with each pump and engine unit. If information is given for the pump alone, pressure and discharge rates for the various speeds will be shown.

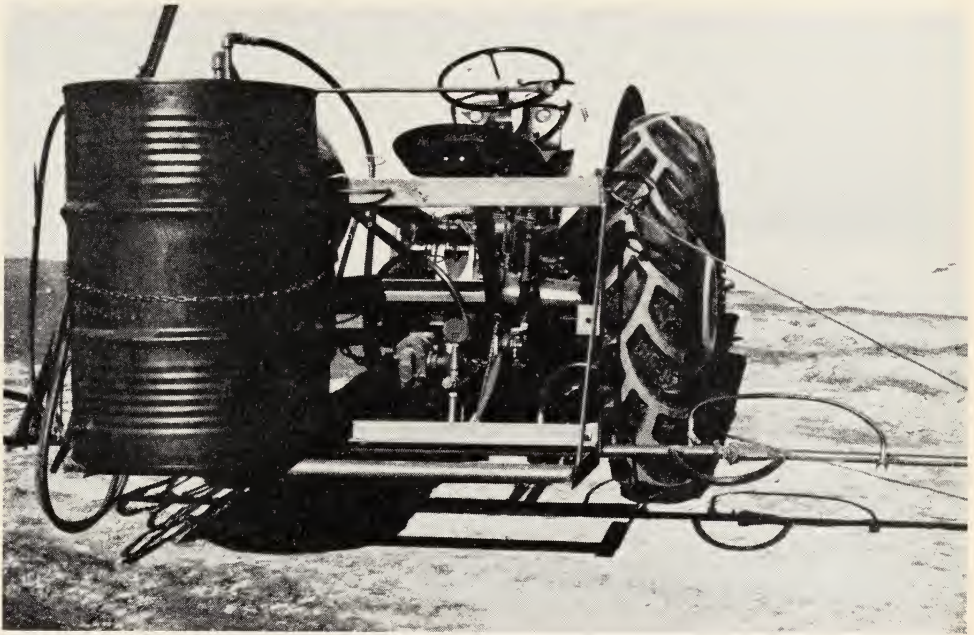
With the positive displacement type, such as the plunger pump, the discharge in gallons per minute at maximum pressure is about the same as the discharge at zero pressure. However, for a centrifugal pump, the discharge at maximum pressure is much less than that at zero pressure. Regenerative turbine and flexible impeller pumps follow much the same discharge pattern as the centrifugal, while rotary gear and other rotaries have characteristics somewhere between those

of the centrifugal and the plunger types.

The water horsepower equation can be used to find the approximate power needed for a given pump:

$$Hp = \frac{\text{lbs. pressure} \times \text{gpm}}{1730 \times \text{efficiency}}$$

Pump tests indicate the efficiency will vary from 20 to 80 per cent, depending upon the pump type and size. Efficiency information can be obtained from the pump manufacturer. Small pumps on weed sprayers are generally very low in efficiency. When figuring horsepower, it is better to use a low figure for efficiency, which will result in an engine with some excess power.



Power for the pump may be supplied by auxiliary engines or by a power take-off drive from a tractor. For a power take-off-driven spraying unit, the pump may be mounted on the tractor, while the tank and boom are on a trailer, or pump, tank, and boom may be carried on the tractor, as shown here. When this plan is used, the pump is either driven directly from the power take-off, or from the belt pulley.

NOTE: A spray unit with an auxiliary engine has an advantage over the power take-off because the auxiliary's speed can remain constant regardless of changes in the tractor's speed. The important factor in choosing either type is to select a drive which will maintain the pump at sufficient speed for the necessary pressure.

Tanks . . .

Metal tanks are better than wooden ones, for spray solutions, because they are easier to clean and less likely to leak. The tank should have a large opening at the top so that it may be cleaned and the agitator may be easily reached for necessary repairs.

The size of the tank depends somewhat on the capacity of the pump, on whether concentrated or diluted sprays are to be used, and on nearness to water supply. In general, if water is readily available, a 300- to 500-gallon tank is large enough. In field spraying, where the tank cannot

be refilled so often, a larger one (1,000-gallon) saves considerable time. If the water supply is some distance from the field, an extra "nurse" tank to haul either water or mixed spray will speed up the spraying operation. The spray pump and motor can be used for refilling from the nurse tank by means of a suction hose and back-fill valve (see pages 7, 13).

For a smaller pump and engine unit, which delivers 3 to 5 gallons per minute by hand boom, a 50-gallon oil drum makes a satisfactory tank.

Care of the Tank . . .

Never use gritty water in the spray tank if it can be avoided. However, if nothing but ditch water is available, be sure to keep as much dirt as possible out of the tank by using strainers on the filling hose. Dirt clogs strainers and nozzles and helps wear out the pump.

Some tanks are galvanized on the inside, some are enameled or coated with plastic material. Others are left bare. The disadvantage of an enameled tank is that thinners used in some oil sprays loosen the enamel, which flakes off and clogs strainers and nozzles. Bare tanks have a tendency to rust, but this may be reduced by carefully draining the tank after each use and flushing it with oil. Rust-preventive oil is best, but used cylinder oil is also of some help.

Special care is necessary in cleaning

tanks in which 2,4-D has been used.

For oil-soluble 2,4-D, rinse the tank first with kerosene. Follow with a rinse of lye or washing soda solution, using 1 to 2 pounds to 25 gallons of water. Leave the solution in the tank for about 5 minutes. Rinse several times with water, preferably hot.

For water-soluble 2,4-D, first rinse the tank with water, then soak the whole liquid carrying part of the equipment overnight or longer, in water. Drain, and run lye or soda solution through the machine. Rinse thoroughly, using hot water if possible.

If these instructions are carefully followed as soon as possible after the machine has been used, no 2,4-D should remain to contaminate other spray materials used later in the same tank.

Agitators . . .

A tank to be used for straight oil sprays alone does not require an agitator, but for all mixed sprays, agitation is necessary. With oil emulsions and heavy suspensions, the agitator must be kept running constantly. With 2,4-D sprays, only light agitation is needed.

Two types of agitator are commonly

used, the mechanical and the hydraulic.

The mechanical agitator is more efficient and generally appears to give best results. This system consists of a series of paddles mounted on a shaft which runs through the spray tank. It is driven by a reduction drive from the pump engine.

The ends of the paddle blades should

have a total width approximately equal to one half the length of the tank, and their length should be sufficient to sweep within $\frac{1}{2}$ inch of the tank bottom. For example, four blades, each 8 inches wide, would be used in a tank 60 inches long. The blade peripheral speed should be between 300 and 400 feet per minute, or 95 to 128 rpm for a 12-inch blade in a 3-foot diameter, 250-gallon tank.

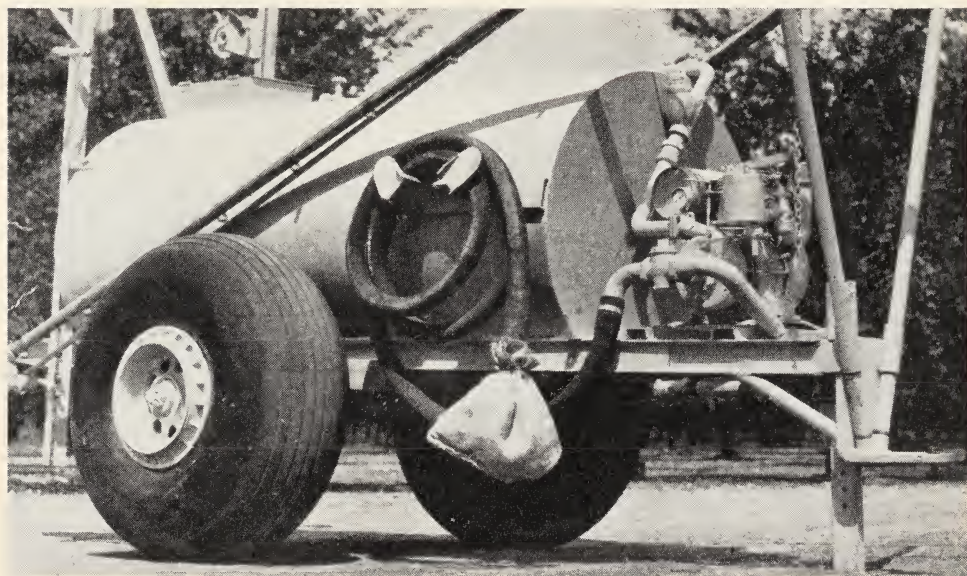
Hydraulic Agitation . . .

Hydraulic agitation requires no moving parts in the spray tank, and is readily installed. A centrifugal pump is generally used with this system because of the high discharge volume needed. The excess flow at boom pressure is recirculated to the spray tank and forced out through many small openings in a 1- or 2-inch pipe laid in the tank bottom. The holes may be fitted with nozzles, if desired, which provide replaceable wearing surfaces. This method of agitation is satisfactory if sufficient recirculation is used. The discharge from the jets should not strike the walls or bottom of the tank through less than

The same length blade in a deeper tank should be operated at a higher speed. The power requirement to drive the agitator increases with the height of the liquid above the paddles. For the example given above, $\frac{1}{4}$ to $\frac{1}{2}$ hp is required. If a flat-bottom tank is used, the rpm of the agitator must be increased 20 per cent; and the power required will be increased 50 per cent.

1 foot of liquid. If it does, the continuous action of the liquid, especially of one containing abrasives, will remove the enamel lining and, in time, may wear out the tank.

No accurate data are available as to the amount of hydraulic agitation flow required for various spray mixes and tank shapes. However, experience indicates that approximately 30 gpm at 100 psi should be provided for a 3-foot diameter, round-bottom, 250-gallon tank. Flat-bottom tanks should have 30 to 40 per cent more agitation. Power requirement ranges from 3 to 4 hp for a tank of these dimensions.



Sprayers with tanks up to 800 gallons capacity may be supported on large bus

or airplane wheels. This spray rig uses airplane balloon tires.

Types of Mountings . . .

The most popular type of mounting for spraying equipment is the two-wheel trailer. The tank is centered over the wheels so that change in volume of spray material does not overbalance the trailer.

Tires and wheels are available in many sizes. Ordinary auto-size wheels (16-inch) will support tanks up to 300-gallon capacity. Heavy equipment with a tank

capacity of 1,000 gallons or over may be mounted on a chassis which is supported by tracks from an old track-type tractor.

Sprayers may also be tractor-mounted, either on the side, or on a power lift frame (see page 5, *A*). Or they may be mounted on skids and carried in the back of a pick-up truck, or in a trailer.



Self-propelled sprayers can be made from war-surplus materials. The one at top is mounted on a weapons carrier and uses a 40-foot boom.

Below: a commercial, self-propelled field sprayer. It uses a 68-foot boom, with electric winches controlled from the driv-

er's seat to raise and lower the boom. Large, tractor-type tires are used. The centrifugal pump is driven by power take-off from the propulsion engine. Tank capacity is 600 gallons; boom output is variable—from $7\frac{1}{2}$ to 500 gallons per acre. Rig speed varies from $\frac{1}{2}$ to 40 mph.

Booms...

Pipe $\frac{3}{4}$ to 2 inches in diameter may be used for the spray boom. It may be of galvanized or black iron, or a light alloy. The 1-inch size is sufficient for a 15-foot boom; $1\frac{1}{4}$ to $1\frac{1}{2}$ inches or larger is recommended for longer booms. Pipe smaller than 1 inch is not practical because the resistance to liquid flow causes a drop in pressure at the nozzles during large-volume spraying. For example, in 10 feet of 1-inch pipe, a 25 gpm flow will cause a 3 psi drop in pressure, which would lower the discharge on the outside nozzles. Further, it is easier to cut holes for nozzles in larger pipe. Finally, larger pipe is stronger and more rigid, so that chances of whipping and possible buckling are reduced.

Small tubing of copper or other metals is sometimes used for very low-volume work with 2,4-D. This small pipe requires some method of support. It does have one decided advantage, in that less liquid is held in the boom and lost by dribbling out on the turns where pressure is shut off.

Large commercial sprayers have power-operated lifts for the boom which allow it to be raised or lowered by electric control from the operator's seat. Similar hand-operated levers are used on a few of the smaller sprayers, both tractor and tractor-mounted types. Ease in raising and lowering the boom helps the operator do a better spray job.

If the machine is to be used for ditch or roadside work, or even for spraying under low trees, it is sometimes good to have the boom offset or entirely on one side of the rig. Where this is done, extra support may be required, either by an outrigger on the outside end of the boom, or by a built-up structural boom to support the liquid carrying line and nozzles (see page 22).

Booms are generally sectionalized and hinged to reduce width when moving between fields or on the highway. When the welded hinge is used, it will block the

ends of each section so that separate feeder hoses, or hoses between sections, are necessary. The separate feeder hose enables the operator to shut off valves on each section feeder and use only the sections desired at any given time. Liquid feed lines from pump to boom should be as short and straight as possible, and no smaller than boom diameter.

Some operators use spring-loaded valves between the boom and each nozzle, which open when the boom pressure exceeds 5 psi and close below 5 psi. These are used mainly to keep the boom from draining when the shut-off valve is closed, but they tend to plug easily and fail to shut off. A recently developed method for stopping boom drainage and dripping is the reverse-flow valve system which places a suction on the boom and nozzles when the pressure is shut off, and draws spray material from the nozzles back into the boom. The suction is provided by discharging the flow from the pump through a venturi or jet when the boom shut-off valve is closed. A 4-way valve makes it possible to combine the main boom-control valve and the suction valve, so that two operations are taken care of by the combination. This is a patented valve and venturi assembly and may be installed on any sprayer.

The length of the boom depends on the types of spray jobs to be done. Booms 40 to 60 feet long are used for open-field spraying in grain, alfalfa, and certain row crops. Shorter booms are used in orchards, for small grain fields, and for some row crops. Row-crop booms are designed to cover a given number of rows or beds. In any case, the length of the boom and the consequent size of the rig will be limited by the size and cost of the tank, pump, and any supports which the boom may require.

The length of boom needed to cover a given acreage in a stated time can be found by the following equation:

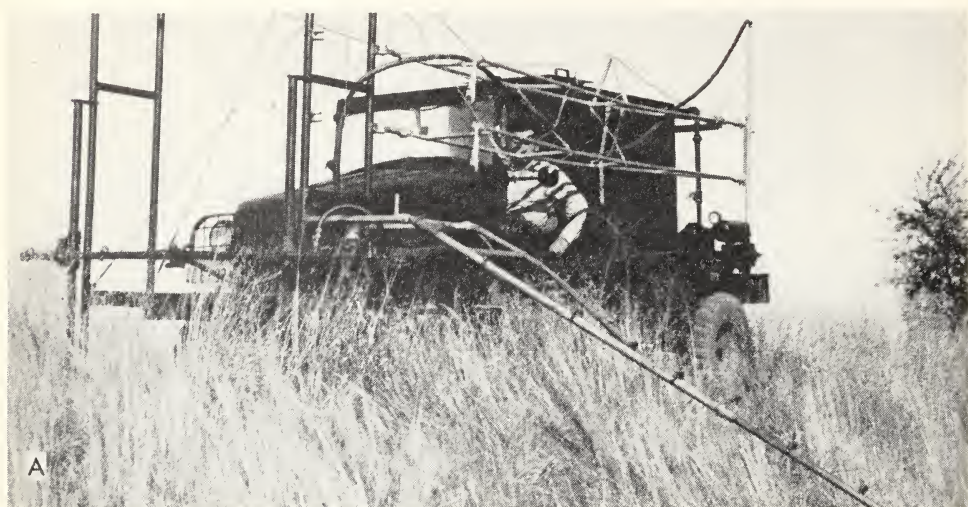
$$\frac{\text{Sq. ft. per acre} \times \text{number of acres}}{\text{Working hours} \times \text{mph} \times \text{ft. per mile}} = \text{length of boom}$$

For example: 250 acres are to be covered, at 5 miles per hour, in 3 eight-hour days. (Assume 30 per cent of total time to be used in filling tank and for turns, leaving 17 actual working hours.)

$$\frac{43,560 \times 250}{17 \times 5 \times 5280} = 23.8 \text{ ft. boom length}$$

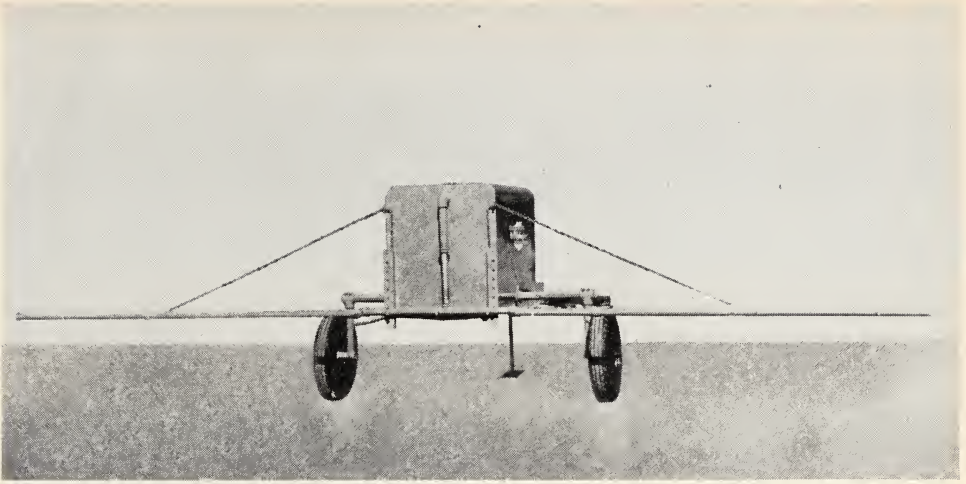
With the same example, we may use a rough rule for finding boom length for general-volume spraying:

At 5 mph, for 3 working days, allow 1 foot of boom for each 10 acres to be sprayed. For the 250 acres, this gives a boom length of 25 feet.



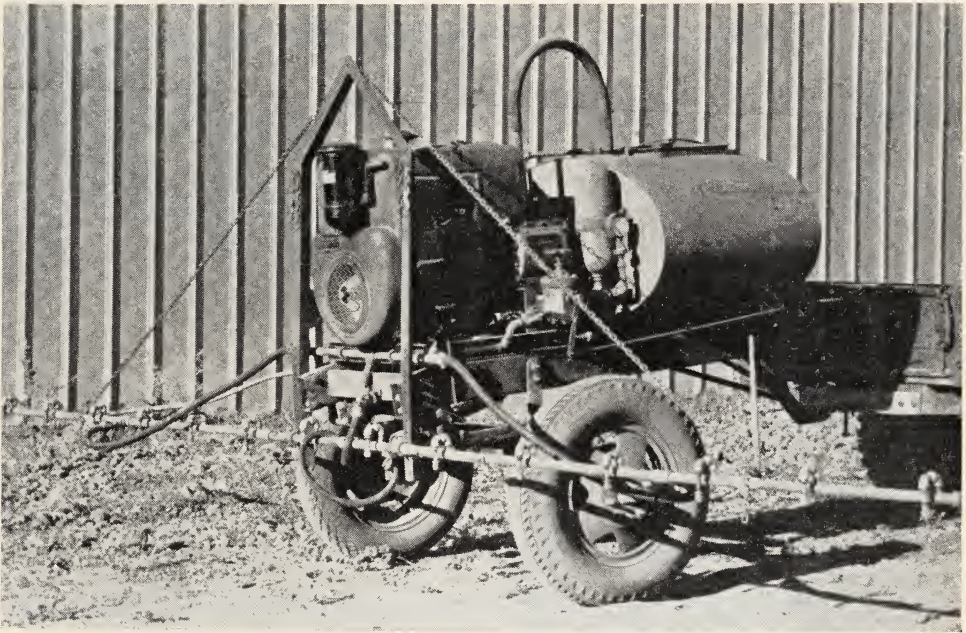
Some sprayers, such as those shown above, are used for special weed spraying along roadsides and ditches.

View *A* shows sprayer in use with ditchbank boom; view *B* is closeup of sprinkler used for ditch-bottom coverage.



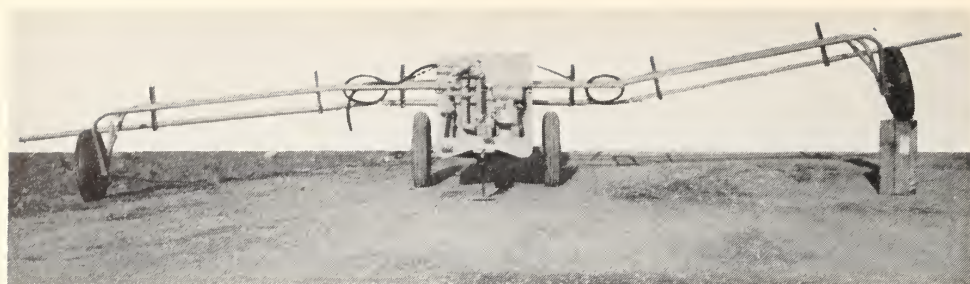
When sprayers are used in fields planted to row crops, the operator must be able to adjust the width of the wheel axle. This may be done by means of mov-

able wheels and bearings mounted on a long axle, or by the use of stub axles and a tubular frame, as shown. An **H** beam may be used instead of tubular frame.



This is a home-built sprayer using a high-pressure plunger pump with a regulator which operates below 100 psi. It has a 3-section, $1\frac{1}{2}$ -inch boom. The boom has vertical support from the light chain, and lateral support from $\frac{3}{4}$ -inch pipe. For raising and lowering the boom, simple

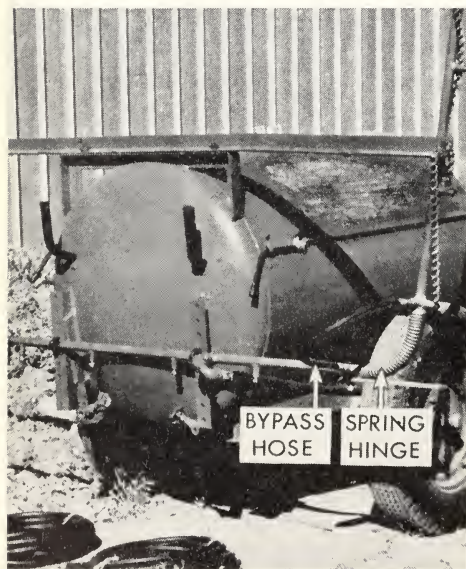
U bolts around the boom are fitted to a drilled frame. The boom may be raised from 10 inches, for small weeds, to 3 or 4 feet for weeds in grain crops. It is built in three sections, with the middle one fixed and the two outside ones hinged to swing up or back, for ease of moving.



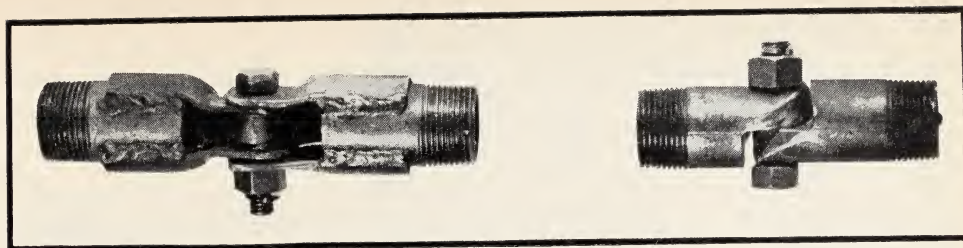
Outrigger wheels used on a jointed boom help keep a long boom parallel to the ground. The boom and wheels may

be made to swing back and trail behind the sprayer so that it is easy to move when not in use.

Some orchard weed sprayers have a hood over the boom to protect the low branches of the trees, particularly in citrus and olive groves. Right: hood has been removed to show how it is held by the angle iron support.

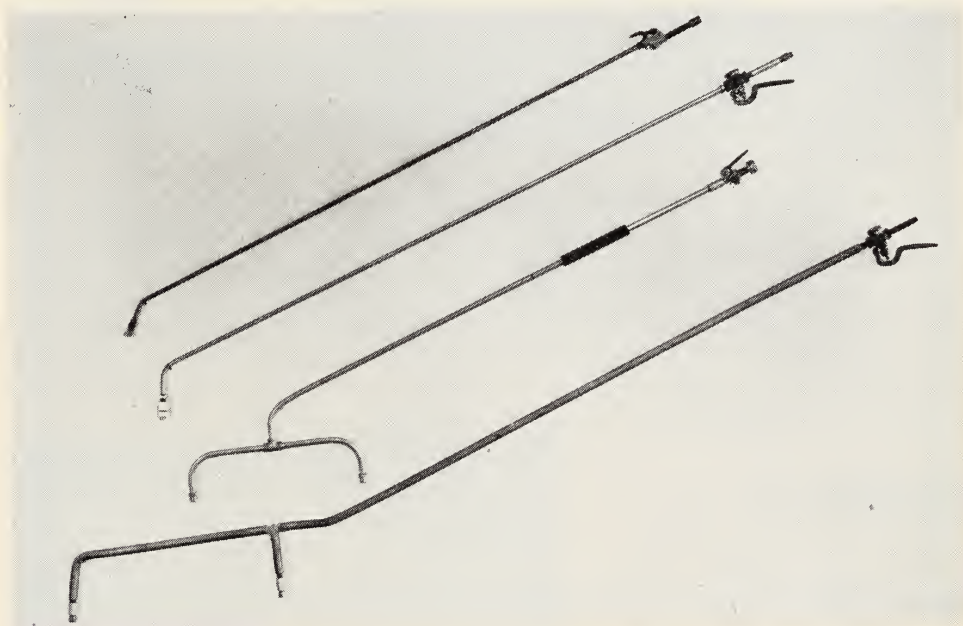


The boom may be hinged with a spring, as shown left. This gives added protection to the boom and to any objects which it might hit in passing, since the coil spring allows it to swing back. This arrangement is also useful for raising the boom to allow passage through gates or for road travel. Note hose for bypassing the liquid around the spring.



Boom hinges or swivel joints may be bought which will carry liquid as they turn. Or a simple welded hinge, such as

the ones shown here, can be made in the farm shop. With this type, a hose may be used to connect boom across hinge.



Hand Booms . . .

For fence rows, scattered weed patches, areas around buildings, and in the garden, a hand boom with a knapsack or small power sprayer is very useful. Hand booms are also used with the large sprayer to cover small areas inaccessible to the fixed boom. The commercially made, lightweight boom with 1 to 3 nozzles, quick shut-off valve, and 25 feet of oil-resistant hose is the most satisfactory. Homemade booms can be built from pipe fittings, but are rather heavy and clumsy if made from iron pipe. Commercial booms are made of aluminum or similar

lightweight metals. It is best to buy the light metal hand booms already formed and threaded for nozzle and hose connection because it is difficult to weld these metals in the farm shop.

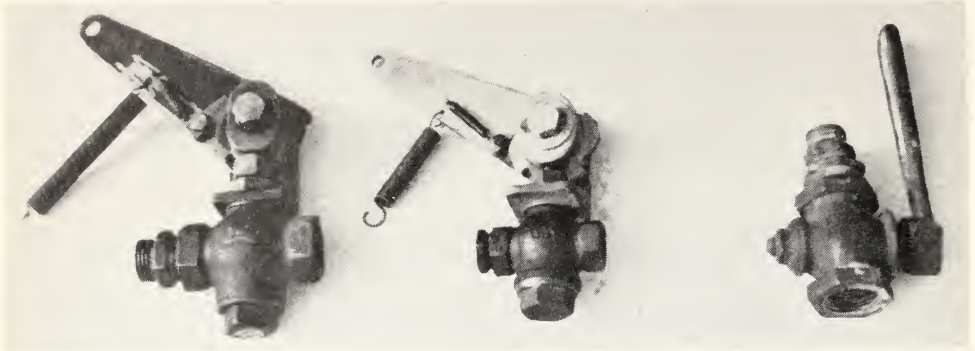
A control valve should be placed between the hose and the boom. The most convenient type valves are spring-loaded, lever-operated. Squeezing the valve lever against the boom with one hand opens the valve; releasing the lever closes it.

The two booms at top are of $\frac{1}{8}$ -inch iron pipe; the two at the bottom are of lightweight aluminum alloy.

Boom Control Valves...

The boom must have a good, quick shut-off valve. Its diameter should be the same as that of the boom, and it should be

placed in the main boom line, with remote control so that the operator can reach it easily.



A good valve for boom control is a spring-loaded poppet type, with ratchet handle and double eccentric. *Left* and *Center*: $\frac{3}{4}$ -inch and $\frac{1}{2}$ -inch poppet valves. A small line tied to the top hole in the ratchet handle is run to the operator's seat. The valve is opened and closed by pulling the line. A pull through about 45 degrees turns the eccentric and opens

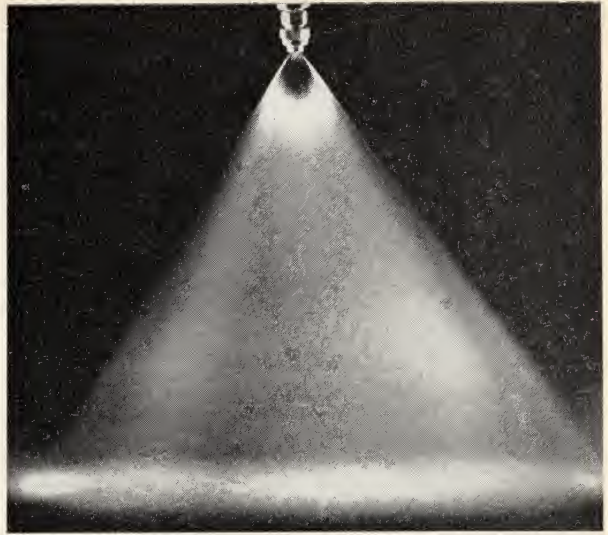
the valve. The handle is then released and the ratchet returns. Another pull turns the eccentric to close the valve. Releasing the handle returns the ratchet to its original position. *Right*: A 1-inch valve with quarter-turn operation. When operated by remote control, a stiff rod is used to push and pull the valve arm for opening and closing.

Nozzles...

Nozzles with either male or female threads are available, usually $\frac{1}{4}$ -inch pipe size. The two types most commonly used are those giving either a flat, fan-shaped spray, or a cone-shaped spray. The tip, or orifice disk, for either type, may be changed by unscrewing it from the nozzle body. Or the opening may be cut in the nozzle itself. If this is done, the entire nozzle must be replaced in order to change the size of the orifice. Most nozzles have small, removable screens to prevent plugging.

A relatively new type of spray applicator is now being manufactured and used for many spraying jobs. It operates on the impulse principle, much the same as the whirling lawn sprinkler. Two nozzles are mounted on short arms and set at such an angle that the discharge of

liquid causes the arms and body of the mechanism to revolve and throw the spray in a large circle. The device is generally mounted in an inverted position on the end of a 10- to 15-foot pipe which carries the liquid spray. The pressure applied to the machine ranges from 200 to 300 psi, and causes the device to revolve at a much faster speed than the ordinary lawn sprinkler. This is necessary to increase atomization of the liquid and produce the droplet size required for adequate spraying and coverage. The pump and storage tank are mounted in the back of a truck, with the boom directly to the rear. A swath 20 to 30 feet in diameter is covered. This type of dispersal gives very little downward drive as compared with conventional sprayers and would be most successful when used with 2,4-D.



Nozzles which produce a flat, fan-shaped spray are considered best because they give the most uniform coverage and strongest drive. This is especially important when spray material has to be forced through heavy weed growth or tall grain.

Above: flat-fan nozzle discharge pattern.

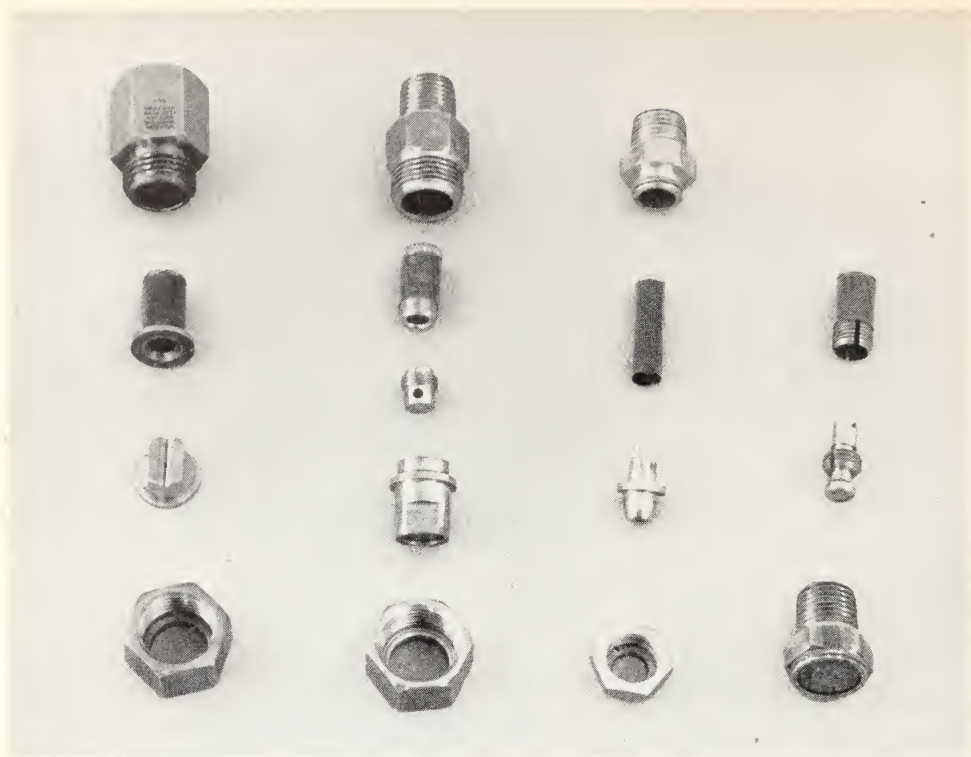
All nozzles require a minimum of 10 to 25 psi before they will fan out or disperse properly. Increased pressure results in greater discharge of gallons per minute, a wider fan, and finer droplets.



Left: Hollow cone nozzle pattern. At high spray pressures, the "bubble" showing at nozzle opening would not occur.

Nozzles which produce a hollow, cone-shaped spray are used by some manufacturers who believe that this type gives greater uniformity of coverage, does not plug so easily, and is less likely to fog

than the flat-fan type at very low discharge rates of 0.03 gpm and under. Small-orificed nozzles, either flat-fan or cone type, discharge small droplets, tend to fog or drift except at very low pressures.



Flat-fan discharge nozzles dismantled to show separate parts. Left to right:

1. Top to bottom: $\frac{1}{4}$ " female body; screen; $\frac{1}{2}$ " tip; holding nut.

2. $\frac{1}{4}$ " male body; screen; insert; $\frac{1}{2}$ " tip; holding nut.

3. $\frac{1}{4}$ " male body; screen; $\frac{1}{4}$ " tip; holding nut.

4. Unit body with nonremovable tip; insert; screen.

Manufacturers make all types of nozzles with a wide range of discharge rates, and with $\frac{1}{4}$ " male or female pipe thread. Note that tips of the nozzles shown above have flat sides for aligning the fan.



It is best to bring the nozzles into the boom from the sides or top. This provides a settling place for dirt particles which may be present in the spray solution or equipment. This also prevents drainage when the boom shut-off is closed. Occasionally, such a boom should be flushed out through removable caps on the ends. Nozzles may be brought into the bottom of the boom with a nipple or coupling raised into the boom to provide settling

space. However, the coupling obstructs the boom line, making it impossible to force rod cleaners through from the ends.

The boom may be drilled, and a 90-degree elbow (1) or a coupling (2) welded over the hole. Or openings may be made in the boom for the nozzles by drilling and tapping the boom, screwing in a street elbow (3) or a nipple (4), and welding in place. Welding is necessary to preserve structural strength. Suitable el-

bows and nipples are used to bring the boom outlet to the proper direction for the nozzles. The outlets may be in a single row, or may be in two rows with alternate nozzles on opposite sides of the boom. This is an advantage when double-coverage application is used. Each row of nozzles is tilted slightly toward the other to give different angles of attack.

NOTE: After any welding has been done, remove the scale and cover the metal with a coat of metal priming paint.

Nozzle spacing on the boom depends upon the type of crop to be sprayed.

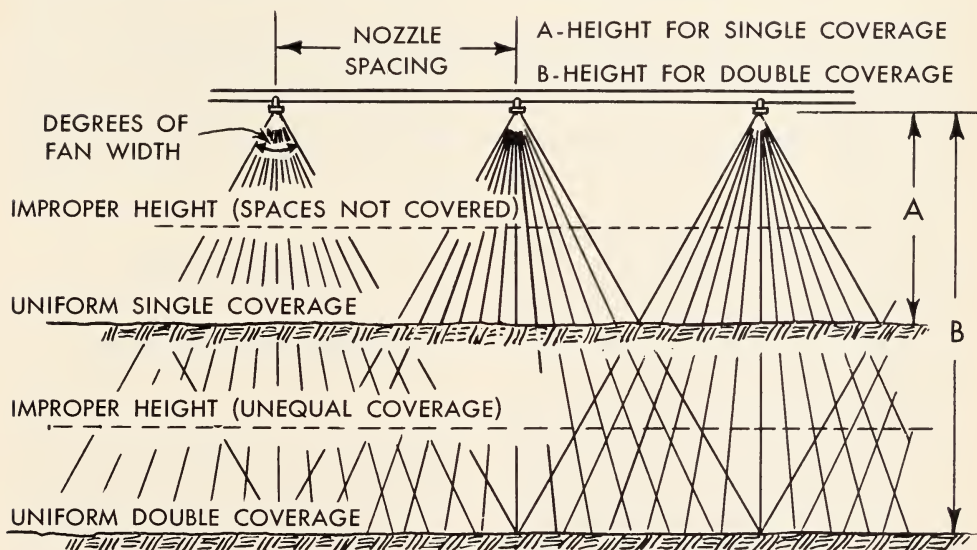
For row crops, the usual arrangement is one nozzle directly over each row, with the boom height adjusted so that the spray fans meet between rows.

Where crops in rows are too far advanced to permit spraying of the foliage, nozzles may be spaced to center between rows. The fans will meet at the base of the rows without wetting the crop plants.

For open-field work, such as grain and

alfalfa spraying, nozzle spacing should be uniform. Since the boom must be kept as low as possible for all applications, short spacings (12 to 18 inches) are used for double coverage or for very low-volume spraying because low-volume nozzles produce narrow fans at low pressures. Wider spacings (18 to 24 inches) are used with wide fan nozzles (80° to 100°) for medium to high discharge and pressure or for single coverage.

Since outlets for the nozzles are welded into the boom, it may be necessary to have extra ones welded in for specific row or bed widths. These may be plugged when other widths are required. Several manufacturers are using hose connections between nozzles, or to the nozzles from the boom, to carry the spray liquid. Special nozzle holders which clamp on the boom may be moved for adjustable spacing. This system is particularly adaptable to rows and beds where plantings are on different widths.



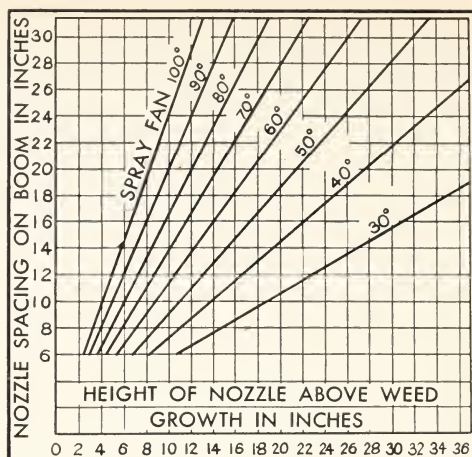
The nozzle fan width and the spacing on the boom determine how high the boom must be above the weed growth to have the fans meet at the tops of the weeds. Double coverage gives the most uniform and thorough application be-

cause each strip of ground is covered by spray from two nozzles. This is especially good for spraying heavy weed growth, for applying contact herbicides, or for operating on rough ground where the boom height changes.

This chart shows the height to which the boom must be raised above the weed growth, with various nozzle spacings, to give single complete coverage.

Double coverage is obtained by raising the boom to twice the height required for single coverage. For example, a boom with 18-inch nozzle spacing and nozzles with 90° fans will give single coverage at 9 inches above weed growth, double coverage at 18 inches.

NOTE: Raising the boom for double coverage does not increase the gallons of spray used per acre.



Calibration . . .

One of the most important considerations in the choice or design of a spray rig is the requirement of the spray job to be done. Suggested volumes and pressures for various spray applications may be summarized roughly as follows:

1. Preemergence oils and oil emulsions: 20 to 60 gallons per acre at 40 to 80 psi.

2. Selective oil sprays in carrots and related crops: 40 to 80 gallons per acre at 40 to 80 psi.

3. Oils and oil emulsions in dormant alfalfa: 100 to 120 gallons per acre at 40 to 80 psi.

4. Selective sprays in grain, onions, peas, etc.: 2 to 120 gallons per acre at 20 to 100 psi. This would include low-volume application of 2,4-D.

5. General-contact herbicides: 100 to 400 gallons per acre at 75 to 150 psi.

These recommendations show the wide range of pressure and volume to be expected in normal weed spraying. Pressure should be held within the limits recommended for the type of application and crop.

The number of gallons per acre a sprayer will discharge depends upon:

- 1. Ground speed**
- 2. Nozzle pressure**
- 3. Nozzle spacing on the boom**
- 4. Size of nozzle opening (orifice)**

1. Ground speed will depend upon the tractor used and the roughness of the ground. Commercial weed sprayers frequently have accurate ground-speed indicators or speedometers, and ordinary farm sprayers may be rigged with them.

An accurate check on tractor speed can be made by laying off a given length of the field to be sprayed and timing the tractor and rig over this course.

For example: The tractor is supposed to do 4 mph in third gear, but it is found that 250 feet are covered in 40 seconds (use a stop watch or one with a second hand).

$$\frac{0.682 \times \text{ft.}}{\text{Seconds}} = \text{mph}$$

$$\frac{0.682 \times 250}{40} = 4.26 \text{ mph}$$

A speed of 2 to 7 miles per hour would cover the range for most spray work. Slower speeds are not economical of time, and faster speeds would be possible only on exceptionally smooth and uniform fields. With most tractors, 4 mph is a convenient speed. It will be seen from this discussion that, while speed is one of the variables affecting gallons per acre applied, it is usually best to stay within rather narrow limits.

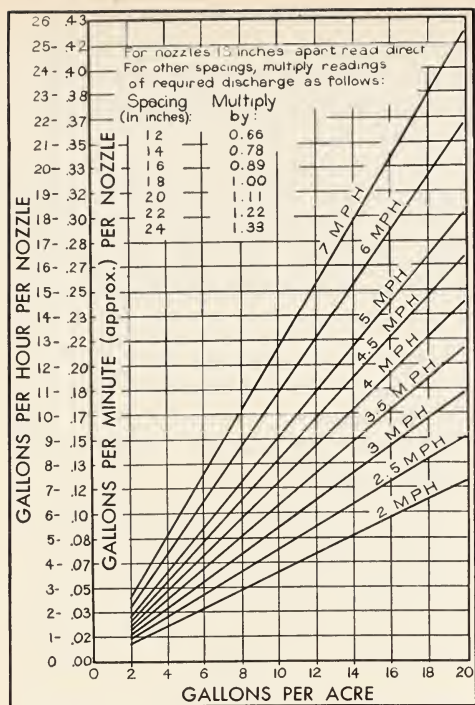


CHART A

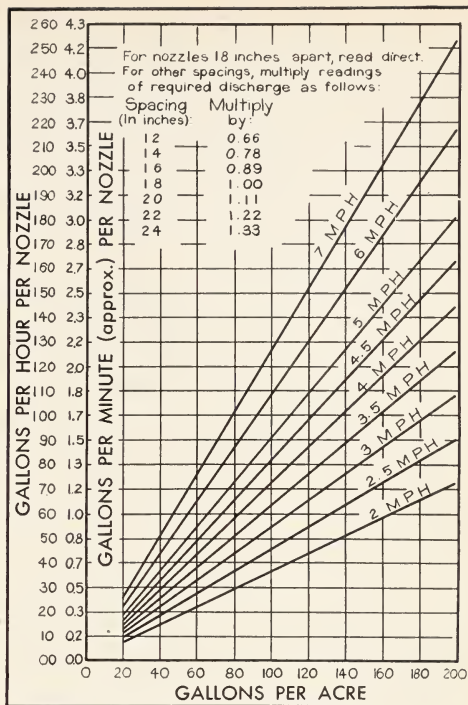


CHART B

Gallons per acre and mph can also be found with these charts. Note that when using these charts with nozzle spacings other than 18 inches, the gpm or gph found from the chart must be *multiplied* by the proper factor as shown, and when the charts are used to find gallons per acre and mph, the answers must be *divided* by this correction factor.

2. The desirable range of nozzle pressures for various spray applications has already been shown. This range allows for some latitude in final adjustment of the pressure to give the desired gallonage per acre.

3. In designing the boom, the nozzle spacing can be chosen which best fits the spray jobs to be done. Once chosen, it is generally not changed.

4. The size of the nozzle opening is the easiest of the factors to change for different spraying requirements. It is possible, with a set of different nozzle sizes, to vary the gallons per acre, over wide limits, with only minor changes in speed and pressure.

5. Another factor indirectly involved with sprayer discharge is the amount of toxicant or active ingredient in the spray mix. This can be altered by adding oil or water to the purchased spray, thus changing the ratio of diluent to toxicant, or the amount of active ingredient which is applied per acre.

The right size nozzle for a particular spray application may be chosen by:

1. Using nozzle manufacturers' charts for a given brand of nozzles.

2. Consulting charts shown above, and nozzle discharge data from the manufacturers' catalogs.

3. Working out the figures mathematically and using the nozzle discharge data from the manufacturers' catalogs.

Charts prepared by nozzle manufacturers frequently give gallons per acre directly for a series of field speeds, pressures, and nozzle sizes. A chart of these variables is prepared for each nozzle spacing. Fan width information may also be on these charts, or may be included as a separate item. The fan width also affects the nozzle spacing.

Nozzles with the same orifice size, but of a different type or made by different manufacturers, will not have equal discharge rates at a given pressure. Nozzle charts or discharge rates for the specific nozzles to be used must be consulted.

There will be some variation in the actual discharge rate as compared to that given in the manufacturers' catalogs because the density and fluid properties of the mixture actually used differ from water, with which nozzles are calibrated. Adding oil increases the discharge. With straight oil, the discharge may be as much as 25 per cent greater than with water. Most suspended materials decrease the discharge as compared with the discharge of water.

Charts A and B have been prepared to show the relationship of pressure, speed, spacing, and gpm discharge, with gallons per acre irrespective of the brand of nozzle used. Chart A is for 2 to 20 gallons per acre; Chart B, for 20 to 200 gallons per acre. They may be used to find the gpm discharge from a single nozzle when gallons per acre, speed, and nozzle spacing are known.

For example: An operator wishes to make a selective spray application at the rate of 75 gallons per acre. The nozzles are spaced 12 inches apart on the boom,

and the tractor goes approximately 4 mph. A pressure of 40 to 80 psi has been recommended for the material being used. The operator's first problem is the choice of nozzle size:

On chart B, he finds the 75 gallons per acre point on the line at the bottom and reads upward to the 4 mph line. He then checks the gpm column opposite the point where the two lines cross. This will give a figure between 0.8 and 1.0, or 0.9 gpm. Looking at the spacing figures (top of chart), he finds that for 12-inch spacing, the gpm figure should be multiplied by 0.66 (0.9×0.66). This is 0.594, or practically 0.6 gpm.

This problem may also be worked out by the equation at bottom of this page.

Having found the number of gallons per minute (0.6) the nozzle must discharge, the next step is to find the specific nozzle size. To do this, it is necessary to use the manufacturer's chart of pressure discharge curves or tables. For purposes of illustration, chart C was prepared. **It is a sample chart, and should not be used for actual calculations.**

On chart C, find the figure 0.6 in the left-hand column, and follow this line across to the right where it first intersects the discharge curve of the 0.078-inch nozzle at a pressure (see bottom figures) of 20 psi. This is too low. Following the 0.6 line farther to the right, it next intersects the 0.059-inch nozzle at a pressure of approximately 68 psi. This is the proper nozzle size and pressure to give the desired application. If nozzles are being ordered without access to a manufacturer's chart, it will be necessary to specify only the required discharge (0.6 gpm)

$$\frac{\text{Gals. per acre} \times \text{nozzle spacing inches} \times \text{mph} \times \text{ft. per mile}}{\text{sq. ft. per acre} \times \text{minutes per hour} \times \text{inches per ft.}} = \text{gpm}$$

$$\frac{75 \times 12 \times 4 \times 5,280}{5,940 \times 60 \times 12} = 0.6 \text{ gpm}$$

ERRATUM:

$$\frac{\text{Gals. per acre} \times \text{nozzle spacing inches} \times \text{mph} \times \text{ft. per mile}}{\text{sq. ft. per acre} \times \text{minutes per hour} \times \text{inches per foot}} = \text{gpm}$$

$$\frac{75 \times 12 \times 4 \times 5,280}{43,560 \times 60 \times 12} = 0.606 \text{ gpm}$$

The constants (ft. per mile, sq. ft. per acre, minutes per hour, and inches per foot) may be combined into 5,940 and used in a shorter formula, as follows:

$$\frac{\text{Gals. per acre} \times \text{nozzle spacing inches} \times \text{mph}}{5,940} = \text{gpm}$$

$$\frac{75 \times 12 \times 4}{5,940} = 0.606 \text{ gpm}$$

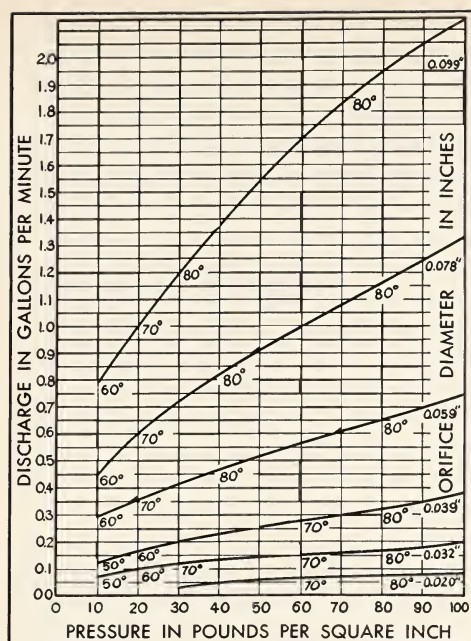


CHART C

at a pressure between 40 and 80 psi. It would also be desirable to specify fan width.

If a large increase or decrease in the output of the spray rig is required, the nozzles are generally changed. However, pressure and machine speed may be changed for smaller variations in coverage. For example, if it is desired to drop from 60 to 40 gallons per acre, while traveling at 3 mph, the discharge on the nozzles will be dropped the amount shown on Chart B, or from 0.55 to 0.35 gpm. Using the sample Chart C, and assuming 0.059 nozzles are being used, this will require a drop in pressure from 56 psi to about 18 psi. Note also that the fan width drops from 80° to 70°. Turning to the chart on page 28, and assuming nozzle spacing on the boom to be 18 inches, it is shown that the boom would have to be lowered about 1 inch, which is insignificant, and would need only to be checked by observing the machine in operation to see that the fans are covering correctly. If the change in discharge

Discharge information in the manufacturers' catalogs may be presented by a chart similar to this, or by tables giving discharge and fan width over a large range of pressures. Most nozzle manufacturers identify their products by the orifice diameter or by the gallons per minute (or hour) discharge at a given pressure. In some cases, the identifying code number also includes the fan spray width at the same pressure.

A change in pressure changes both the discharge rate and the angle of the fan. For example, on the chart, a nozzle which discharges 0.15 gpm at 10 psi liquid pressure will discharge 0.30 gpm at 70 psi. This same nozzle, at 10 psi, gives a 60° fan. At 80 psi, the fan increases to 70°, and at 100 psi, to 80°.

NOTE: This chart is a sample only. When ordering nozzles, check the manufacturers' catalogs for fan angle as well as discharge volume for a given pressure.

cannot be accomplished without too great a drop or increase in pressure, then the nozzles will have to be changed or the rate of travel increased.

Using the same example, that is, dropping from 60 to 40 gallons per acre, with a nozzle discharge of 0.55 gpm, the new coverage rate can be obtained from Chart B by increasing the speed from the 3 mph to about 4½ mph. (Move left on the 0.55 gpm line, from 3 mph intersection with 60 gallons per acre, to 4½ mph on 40 gallons per acre.) If the ground is too rough to travel at this new speed, and the pressure cannot be dropped, the nozzle size will have to be changed.

After the nozzles have been chosen and installed, it is advisable to check the discharge before going ahead with the job. A rough check on the gallons per acre can be made in the field during the first two or three rounds. First, find the number of acres that are being covered in one round, then measure accurately the amount of spray that has been discharged. This may be done either by de-

termining the amount required to refill the tank, or by using a measuring stick calibrated for the tank. Dividing the number of gallons by the number of acres covered will give gallons per acre.

A more accurate method may be advisable to find the coverage which will be applied under operating conditions, particularly with low-volume applications. Measure the actual discharge of spray mix from a single nozzle, in a given time, in a pint or quart bottle or graduated glass. The gallons per minute discharge can then be figured from this. Following the previous example, if 5 pints are discharged in 1 minute, divide 5 by 1 to get pints per minute, or 5. Then divide by 8, to change pints to gallons, which gives 0.624 gpm for this example, instead of 0.6 gpm which was expected.

The exact gallons per acre can now be found by using the corrected discharge (0.624 gpm) and the actual tractor speed (4.26 mph). From the mathematical relationship on page 30, gallons per acre for one nozzle equals:

$$\frac{5,940 \times \text{gpm}}{\text{nozzle spacing inches} \times \text{mph}} = \text{gallons per acre}$$

$$\frac{5,940 \times 0.624}{12 \times 4.26} = 72.5 \text{ gallons per acre}$$

Strainers . . .

Dirt, sand, and lumpy materials in the sprayer plug nozzles and cause excessive wear on pumps and regulators. Strainers installed at strategic points in the sprayer will reduce these losses.

The tank opening should have a 50- to 80-mesh (number of holes per linear inch) screen to keep out large particles and lumps from improperly mixed spray liquids. A similar mesh screen should be placed in the suction line to the pump, to keep dirt particles out of the pump and

If the discharge is raised to 0.65 gpm by increasing the pressure a few pounds, the desired figure of 75 gallons per acre is reached.

Small, hand-boom sprayers or knapsack sprayers may be calibrated roughly by measuring the volume discharged in a given length of time. It is possible to figure how long it will take to cover a given area, if the required gallons per acre are known, by figuring the gpm of the hand boom at various pressures and with different nozzle sizes.

Low-volume applications are difficult with a hand boom, and accuracy is possible only if small, measured areas are sprayed with a definite volume.

The large power sprayer should be calibrated as closely as possible so that the operator can choose the correct values for the variables noted (p. 28) to produce the required volume in gallons per acre.

The ordinary farm sprayer may be rigged with a speedometer and special discharge meter to simplify calibration and operation.

out of the tank when the backfill is used. Another point to be screened is in the boom line from the pump, between the pressure regulator and the boom. This screen should have an area of about 100 square inches, for a general-volume sprayer, with openings of 100 to 150 mesh. The last point for screening is in the nozzles themselves, where small screens of 50 to 200 mesh are used, depending on the size of the nozzle opening. Do not depend on these nozzle screens to

do the job of the boom-line screen, because their area is much too small, and they quickly become plugged.

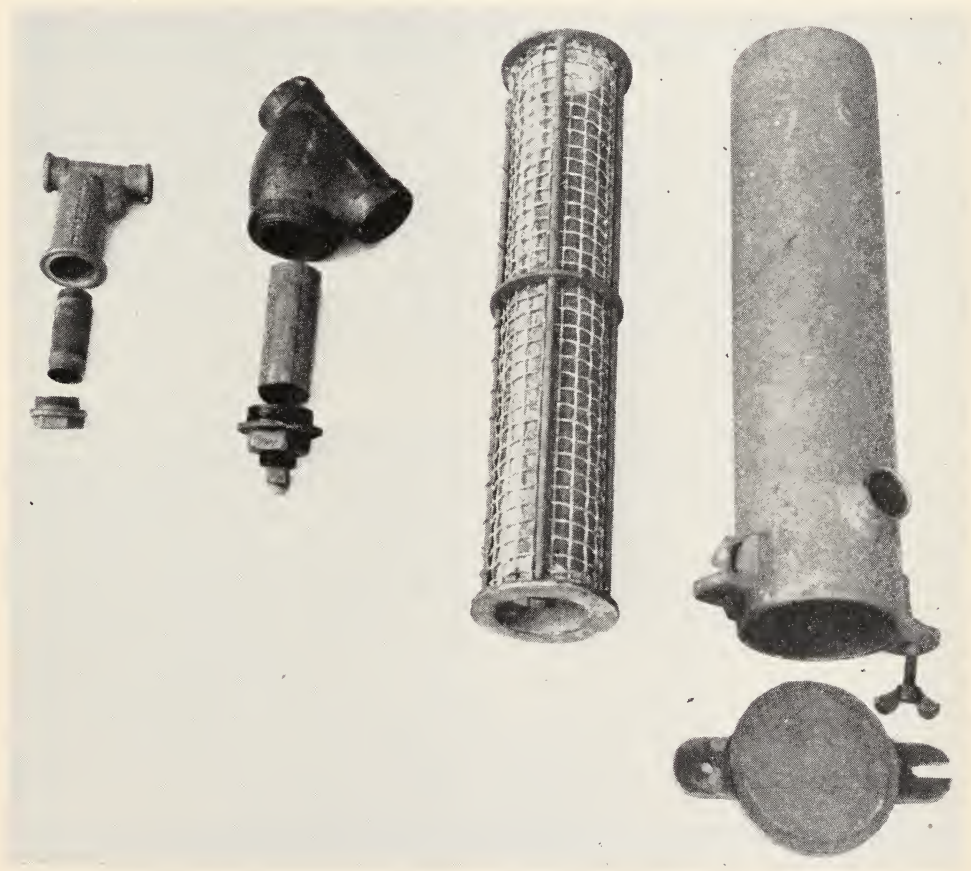
Pump-inlet and boom-line screens can be made detachable, for cleaning, or can be of the back-flush type if the flushed

material can be run out of the machine. One manufacturer provides continual screen flushing by drawing liquid and dirt off the dirt collecting side of the screen, using a jet in the pump line to the tank to provide the liquid flow.

Pressure Gauges . . .

A properly calibrated pressure gauge of good quality should be installed in the line from pump to boom, between the boom and the shut-off valve. The gauge should be 3 to 4 inches in diameter, with a maximum reading of 150 to 200 psi. It

should be easy to read from the operator's seat on the spray rig. Have gauges calibrated each season by a reliable pump or sprayer service, or check them against an accurate gauge to make sure their readings are correct.



Boom-line strainers with removable screens. Left to right: 1. **T** type with an area of 6 square inches; 2. **Y** type, with

16 square inches of screen; 3. Home-built strainer (and cover) with 120-mesh screen and about 150-square-inch screen area.

Pressure Regulators . . .

Various types of pressure regulators, relief valves, and reducing valves are found on weed sprayers. Positive displacement pumps require a pressure regulator or relief valve with bypassed flow to take care of the liquid flow from the pump when the boom is shut off. These regulators on high-pressure plunger pumps frequently have a built-in unloader valve which takes the load off the engine and pump when the boom is shut off.

The relief valve, or regulator, consists of a spring-loaded valve with an adjustable spring tension. This bypasses excess flow from the boom and returns it to the tank. Pump pressure drops with increased flow, and the regulator bypasses whatever amount is necessary to keep the boom pressure constant. There has to be a small amount of bypass flow at all times during operation, or else the pressure will drop below that for which the spring tension of the regulator is set. Frequently, the high-pressure orchard pump regulator will not operate satisfactorily below 100 psi. If the pump is used for low-

pressure spraying, a low-pressure regulator must be substituted or a pressure reducing valve must be used in conjunction with the old regulator.

The diaphragm, or pressure reducing valve, is similar to the common oxy-acetylene reducing valve, but is designed for liquid operation. There is no bypass flow with this device. The pressure may vary on the input side, but pressure on the output or boom side of this valve will be relatively constant. Valves are bought for a specific pressure output range and a given maximum input. The hand screw on the valve is set at the pressure desired with the boom turned on.

Another control, consisting of a simple, screw-operated globe, or gate valve, may be used to control pressure from a nonpositive displacement pump. The valve is adjusted to the pressure required with the boom shut-off valve opened. Boom pressure with this control will, however, vary with pump pressure, so that such control is not suitable unless pump pressure and discharge are relatively constant.

Pressures . . .

High pressures are not necessary for weed spraying. Tests show that pressures of 100 to 125 psi are fully as adequate as higher ones, and for many spray jobs, lower pressures are desirable. They also have certain advantages:

1. Low-pressure equipment is less expensive than high-pressure equipment.

2. There is less tendency for the spray to fog or drift at low pressures.

3. Large nozzles may be used at low pressures to apply the same number of gallons per acre as smaller nozzles at high pressures. This cuts down on nozzle plugging and gives a more uniform coverage.

Most nozzles do not give a uniform droplet size but a band of sizes. For example, the range on the band may be from 10 to 150 microns (see page 40), these

figures representing diameter of the droplets. When increased pressure causes droplets to become smaller, the band of sizes shifts toward the smaller end. There are then fewer droplets in the 150-micron range, more in the 10-micron range, and probably some additional ones below 10 microns. The range around 30 microns and below is classified as an aerosol (airborne) and is highly susceptible to drift.

Penetration and distribution are a function of pressure with a given nozzle. Maximum penetration or drive is obtained with large droplets at high pressure, but increasing the pressure on a given nozzle reduces the droplet size. Distribution is best with small droplets which cover the weeds most thoroughly, but the smaller droplets are more susceptible to

drift. A compromise must be made and an optimum pressure used to give satisfactory penetration without serious drift.

The factors that determine optimum nozzle pressure are variable, but depend largely upon the size of the nozzle orifice, the design of the nozzle, and the physical characteristics of the liquid. The optimum pressure goes down with smaller orifices, so that for nozzles around 0.03 gpm and under, the maximum pressure should not exceed 30 to 40 psi. These small nozzles are used for 2,4-D applications of 2 to 5 gallons per acre.

Nozzles of different design, even though they have the same orifice size, may have different optimum pressures. The amount of suspended or dissolved material in the spray liquid alters the nozzle pressure characteristics. When oil is added to a

spray solution, increasing the amount decreases the droplet size, all other factors remaining constant, and may increase the discharge by as much as 25 per cent.

High pressures are generally used with water solutions, and for general-contact spraying of heavy weed growth where fogging and drift will cause no harm. Some operators believe high pressure and drive are necessary to get complete uniform coverage when spraying under windy conditions. Lower pressures are used with oil sprays, with 2,4-D or other translocating sprays, for short weed growth, and in any area where fogging or drift might cause damage.

The operator must take into account the various influencing factors for each spray job and decide in each case how the sprayer shall be operated.

Airplane Sprayers . . .

The use of airplanes for weed spraying has developed rapidly during the past two years. The armed services used several methods for applying DDT by plane; but weed spraying, in most cases, requires more control of the discharge, and larger spray droplets than are delivered by the machines designed for DDT.

Airplane spraying has the advantage of speed which makes timely application possible. Further, spraying is not held up by irrigation water and ditches, or by wet fields. For translocating sprays, such as 2,4-D, the application of spray material by plane is very satisfactory. However, for heavy weed infestations, and in other situations requiring large-volume spraying and deep penetration of the weed growth with contact sprays, the ground sprayer does a better job.

Over 100,000 acres of crops in California were sprayed for weed control by airplane in 1947. Various spray materials were applied on grain, rice, alfalfa, in orchards and on row crops, as well as on drainage and irrigation ditches. Where speed is important, or where the ground

rig cannot operate, the airplane and helicopter undoubtedly will become the main methods of applying weed sprays.

Cost of application by airplane is at present from \$1.50 to \$2.00 per acre, for the average spraying job. Because the airplane can only carry a limited payload—800 to 1,000 pounds for fixed-wing planes and 400 pounds for helicopters—the spray mixture will be more concentrated or have less diluting oil or water than that applied by ground rig for the same job. For example, certain selective sprays are applied with a ground rig at 80 gallons per acre, but will be applied by plane, with the same amount of active ingredient, at only 15 to 25 gallons per acre. When heavier volumes are desired, or when there is no airport near the field to be sprayed, the charges per acre will be increased or will be made on a per-gallon basis. Some operators have a graduated scale of charges which go down as the number of acres to be sprayed increases. Unusual spray jobs are sometimes contracted for by the plane operator on a flat charge per hour of operation.

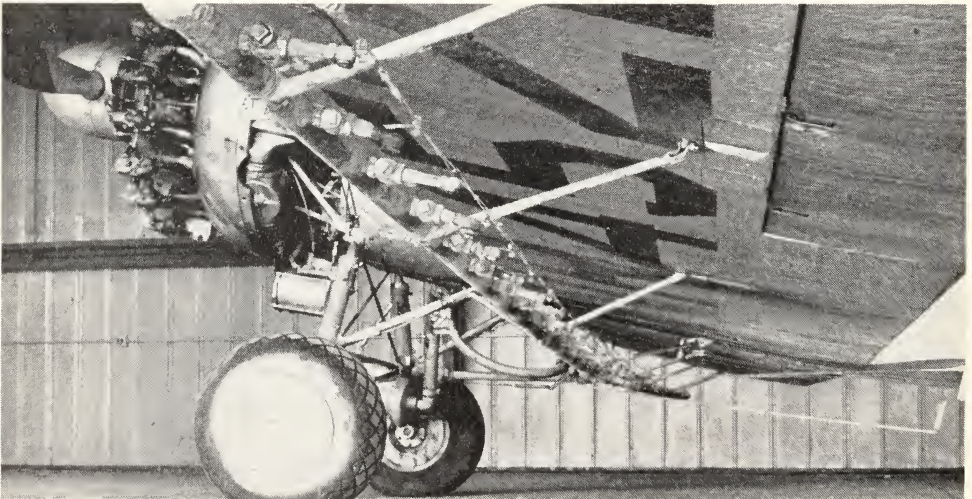
Most airplane sprayers use booms and nozzles similar to ground sprayers. Right: Wing length boom.



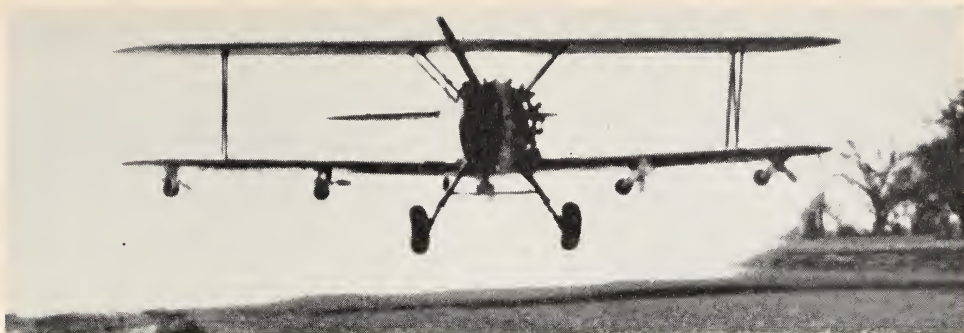
Left: Plane with shorter boom—6 to 8 feet.

Planes used for weed spraying are generally biplanes, such as the old Travelaire, war surplus N3N's, and later models made by Stearman, Boeing, and others.

These planes are frequently equipped with larger engines than normal—sometimes 350 to 400 hp—to make them easier to maneuver and safer to work with.



Plane with winglength boom. Pump is externally mounted (between landing wheels). Boom is tapped from rear. Nozzles are individually controlled by small poppet valves operated through cable controls from cockpit.



Another type of distribution is the rotary, shown here. This consists of two to four rotating brushes, disks, or hollow propellers, 8 to 12 inches in diameter, located on the ends of propeller shafts under the wings. The spray material is fed,

by gravity, from the storage tank through valves to the hollow hubs of the rotors, and is thrown outward into the slipstream of the propeller and the down-wake from the wings. No pumps are required for this system.

There are two other types of distribution, neither of which is widely used for weed control because of certain disadvantages. One is the breaker bar system, used for DDT spraying for mosquito control. This equipment consists of a pump, control valves, and booms. The booms are located under each wing, and are drilled at intervals of about a foot or more. The boom discharge at about 100 psi strikes a prismatic bar between the boom and the trailing edge of the wing.

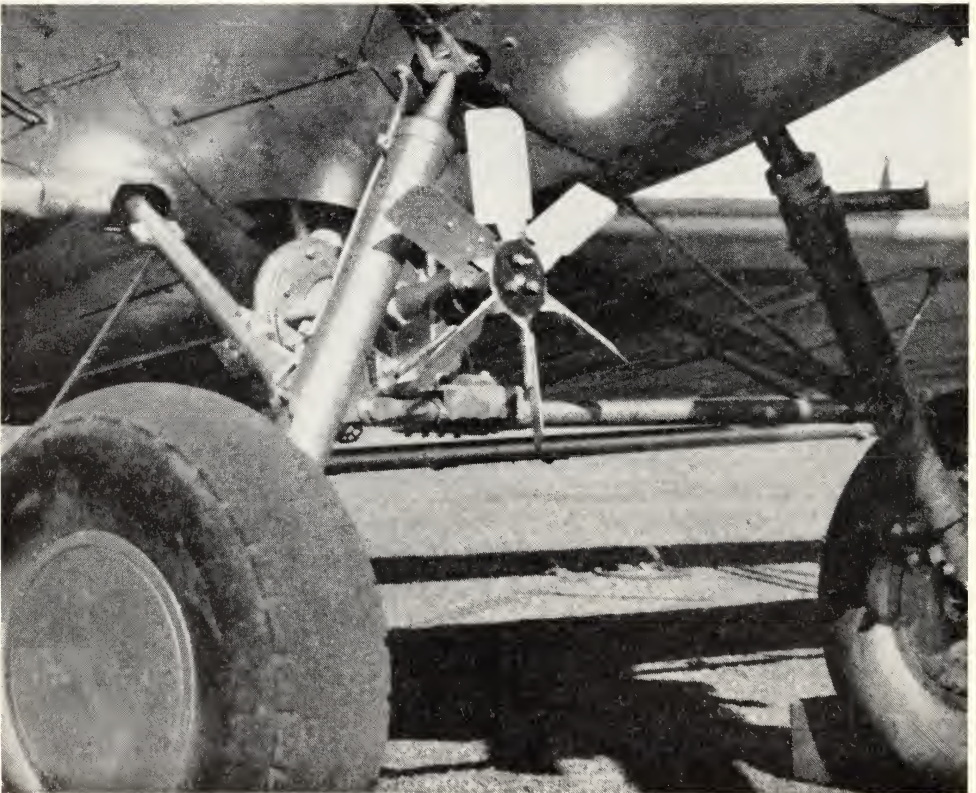
The resulting spray is a wide swath of fine droplets. This system is rarely used because the droplets are too small, and it is difficult to control the width of swath and the amount of liquid discharged.

The other system is an engine-exhaust aerosol whereby liquid material is fed into the engine exhaust and discharged as very fine droplets (10 microns and under). Both systems produce droplets which classify as an aerosol and are not suitable for weed spraying.

Spray liquid is carried in a 100- to 150-gallon tank on fixed-wing planes, and on a tank about half that **size** for helicopters. Tanks are equipped with an agitation system—generally hydraulic—using the excess flow from a single-stage, centrifugal pump, which also provides pressure from 20 to 150 psi to the boom and nozzles. Booms, pump, and connecting pipe are generally made from aluminum or light metal alloys, and may be bought from manufacturers specializing in airplane spray equipment, or made up by individual operators.

The pump may be mounted outside the fuselage and driven by a small propeller, as shown below, or may be mounted inside and driven by an electric motor. Another method is to mount the pump behind the main engine and drive it through a **V** belt power take-off and a clutch. This makes it possible to disengage the pump drive when not in use.

The helicopter is entering the weed spraying picture. Users claim it gives better crop penetration because air is mostly forced downward by the rotor instead of into a horizontal, high-velocity slipstream such as from the fixed-wing plane. In either case, the amount of displaced air is proportional to the weight of the plane and, to a lesser degree, to the horsepower of the engine. The greatest evident factor in favor of the helicopter is its maneuverability in closely bounded fields. This is due to its controllable, low ground speed and ability to rise almost vertically. One factor against widespread use of helicopters is the cost—roughly five times that of a comparable fixed-wing plane. Another is the greater flying skill required, which necessitates using specially trained pilots. The helicopter shown on the following page has a boom with cluster nozzles (no individual control) and side tanks for liquid.





Nozzles for airplane spraying are tapped from the top or side of the boom and are generally controlled by quick shut-off valves for each nozzle or group of nozzles. The valves may be spring-loaded or positive-action, of either gas cook or poppet style. Some operators use automatic, spring-loaded ball valves similar to those on ground rigs. Quick shut-off valves are essential to stop the liquid flow at field boundaries. These valves are controlled (by the pilot) with a small cable running the length of the boom and back to the cockpit. Nozzles may discharge either a cone or fan type spray.

The method described on page 19 for ground-rig booms, using suction on the boom while boom pressure is off, has been adapted to use by planes. The width or coverage of the spray is not so greatly affected by the length of the spray booms as it is by the wing span, the height the plane flies, the design and power of the plane, and arrangement of the boom and nozzles with relation to airstream. Droplet size is greatly affected by the angle at which the nozzles discharge into the airstream. Smaller droplets occur when the nozzles are directed against or across the airstream than when they are directed

with it. Droplet size is mainly influenced by pump pressure, but the very small nozzle orifices will also decrease the average droplet size, depending upon the type of nozzle. A compromise must be made between the small droplets which give more thorough coverage but have a tendency to drift, and the large droplets which settle fast but are not so efficient with respect to coverage. (The number of droplets per square inch varies inversely with droplet size.) The average size deposited by correctly operating airplane equipment is between 50 and 300 microns, at which size most weed spray materials react satisfactorily.

Strainers are not generally used because nozzle orifices are large. However, spray material must be carefully strained before it is placed in the plane tank. Some operators believe that a boom strainer reduces valve and nozzle plugging.

A nurse and mixing tank is used to mix the diluent and chemicals and to transport them to the field from which the plane is operating. Because the time for discharging the spray load is very short, the other time consuming operations—flying to the landing field for refilling, and the refilling operation itself—should

be done as quickly and efficiently as possible. The nurse tanks may be old orchard sprayers, or special units built for this work—small pumps and engines mounted on 200- to 400-gallon tanks. The pump and engine are used to mix and agitate the spray liquid and also to pump it into the plane. The plane tank may be filled from the top of the tank itself, or through

one end of the boom with a special hose connection and shut-off valve. Some operators are considering the use of a ground sprayer to complement the airplane equipment and work the field boundaries and small areas difficult to cover by air. The nurse tanks could easily be converted to such complementary sprayers.

Dusting . . .

Tests on present commercial dusts show that about 70 to 80 per cent of such dusts is in particles ranging in size from 1 to 10 microns (25,000 microns equal 1 inch). This chart shows the drift to be expected when various sizes of water droplets are allowed to fall through 10 feet of air the

average velocity of which is 3 mph. The chart was prepared from data on actual rate of fall measurements, and gives an average drift. As the chart shows, 10-micron water droplets will drift one mile before falling 10 feet. Lighter dust particles drift considerably farther.

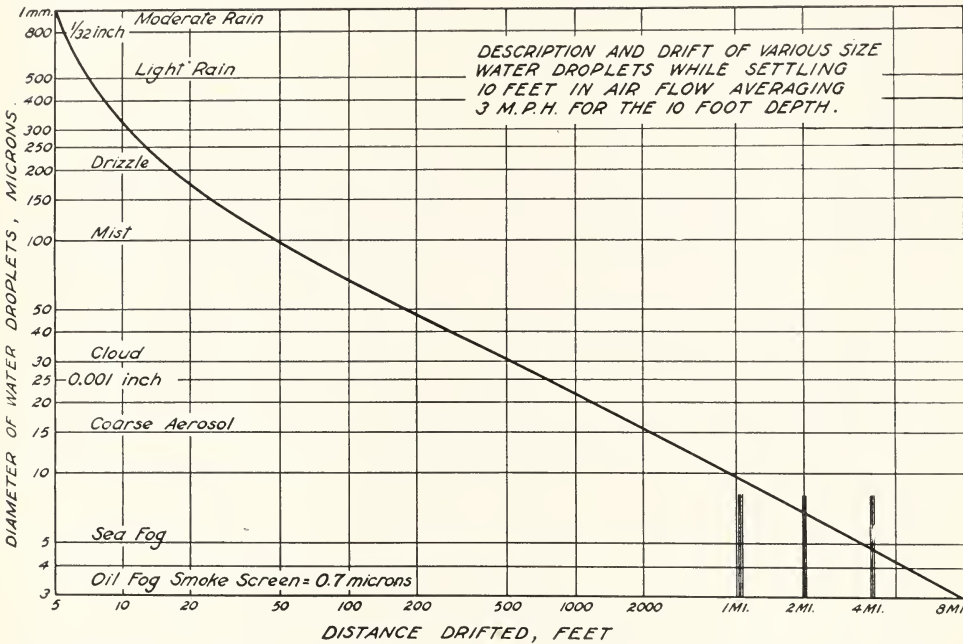
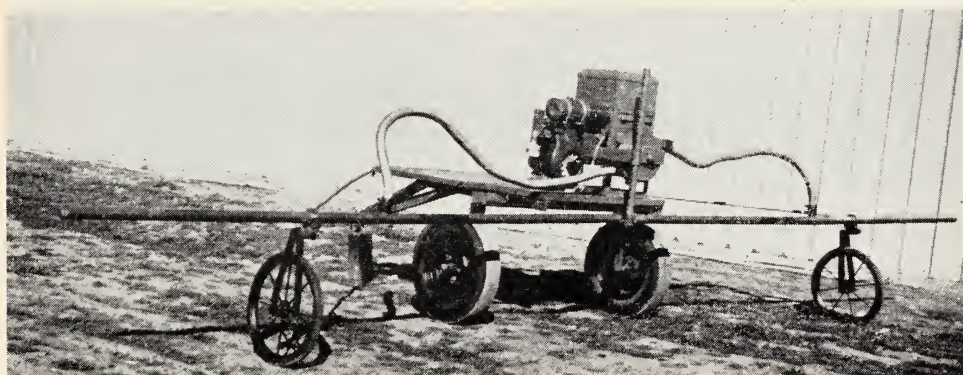


Chart from: Brooks, F. A., The drifting of poisonous dusts applied by airplanes and land rigs. Agricultural Engineering. 28: 6 (June, 1947).

Dusting has certain advantages over spraying, for weed control. Dust may be applied by hand-operated machines—either pack-back or cart style—or by power-driven ground dusters. The Civil Aeronautics Authority has forbidden the application of 2,4-D dust by plane, but

other herbicidal dusts may still be used. Dusting is cheaper than applying liquid spray, either when done commercially or by the farmer himself. No mixing with water or oils is required, so that no extra help is needed, as for mixing spray. Usually, a wider swath can be taken with a

duster than with a spray rig. However, there are significant reasons why the dusters available today are not more commonly used for weed work. First, and most important, is the high loss through drifting of dusts. It is difficult, with drifting, to build up a sufficient amount of dust on weed growth to kill it. Second, if toxic dusts are being used, the drift may cause severe damage to near-by crops, shrubs, bees, and animals.



Discharge equipment for ground dusters may be single-nozzle, multiple-nozzle, or boom type. Single-nozzle machines have been used very little outside of experimental plots on hillsides and gulleys, where standard rigs cannot operate. Multiple-nozzle machines, such as are used for row crops, may have the nozzles spaced along a boom, to give uniform discharge over the application width. The boom type machine shown here is the one most commonly used at present. Booms may be tapered or straight, of metal or canvas. Tapered booms and internal baffles are used in attempt to control uniformity of discharge. Long booms, like the one shown above, are generally supported by outrigger wheels and jointed for flexibility in going over rough ground. The blower usually discharges into the 3- to 6-inch diameter boom at two points.

Hoppers for carrying the dust vary in size, depending on the number of nozzles and the length of the boom. Agitation of the dust is necessary, and is accomplished

Dusting can only be done under calm weather conditions. But ground or air-plane spraying can be safely done under mildly windy conditions of 8 to 12 mph. However, this is not meant to imply that spray, particularly if applied by plane, does not drift.

Spraying by ground rig or plane costs more per acre than dusting, but it gives much greater control of the drift factor, and is therefore preferred to dusting.

by rods, scrapers, or brushes mounted in the hopper—generally over the discharge point. Manufacturers have done very little to insure uniform feed with changing dust level to maintain fluffiness of dust and eliminate separation of active dust and diluent. Double-bottomed hoppers and auger lifts for top feeding have been used with notable advantage over the standard hopper. Adjustable feed is commonly obtained by using slots or holes with a sliding cover in the bottom of the hopper. Outlet for the dust is connected to the intake of the blower or fan, and a certain amount of suction from the fan is used to draw the dust from the hopper to the fan.

All of the many types of blowers and fans have been used on dusting equipment. Accurately built centrifugal or radial-flow fans with multiple blades are used, as well as the rougher, paddle type centrifugal with 4 to 6 welded steel blades. More recently, a number of dusters have appeared using propeller or axial-flow fans with either double or 4-bladed pro-



pellers or the multiple blade of disk type turbines. The more efficient blowers are higher priced but will handle more air per horsepower.

The various air-diluted sprayers (mist, vapor, and dew dusters or sprayers) have not been used to any great extent for weed control to date, but show promise for the future. Such names have also been applied to dusters having water-discharge nozzles which inject into the dust stream in an attempt to reduce drift and increase the dust catch. The toxic material must be in the liquid to qualify the machine as a sprayer. These machines are of the so-called concentrate or air-diluent type. High-volume air from a blower similar to that used on an ordinary duster is passed through a special nozzle containing a smaller liquid discharging nozzle or shearplate from which the air picks up the liquid, atomizes it, and carries it to the plants. In this way, the air acts

as a carrier and dispensing agent, and requires only one half to one fourth as much water as the usual sprayer.

Ground dusting, while less hazardous than airplane dusting, can only be done under calm weather conditions in early morning or at night. Hoods have been mounted over the dust discharge of ground rigs and down to the ground level, in some cases being dragged over the ground for several feet behind, to form an area wherein the dust could settle. Another practice has been that of adding oil to the dusts to stick fine particles together and increase the rate of fall. However, it was found that while a certain reduction of drift takes place with either of these methods, in most cases the amount is not sufficient to warrant the inconvenience.

The accompanying air views show drift from a dust application by ground rig, under very calm weather conditions.

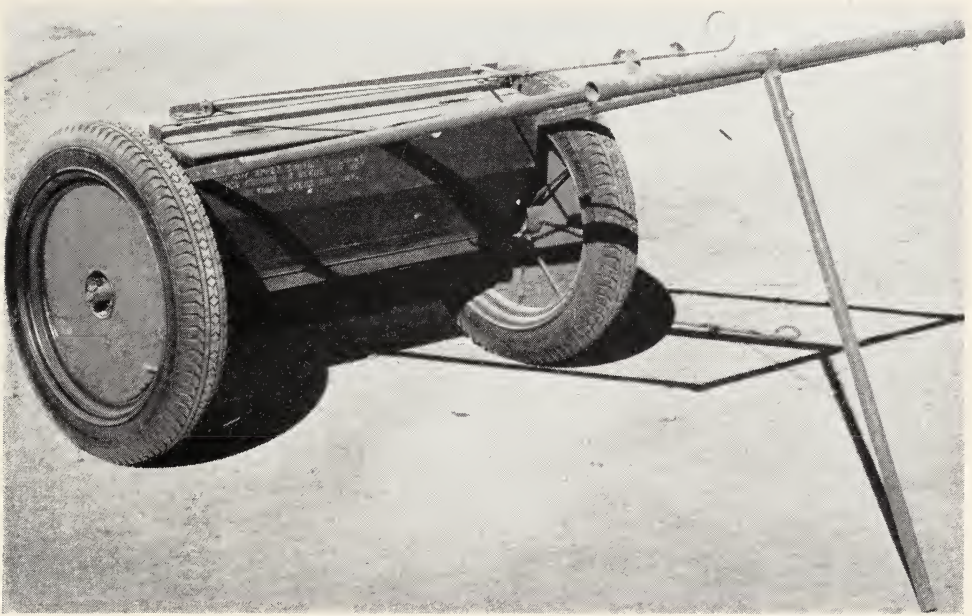
Soil Sterilants . . .

Soil sterilants are used for controlling all vegetative growth on such areas as driveways, fence rows, roadsides, ditch banks, railroad rights-of-way, and fire-breaks. Soil sterilants are classified loosely as permanent or temporary, de-

pending upon the length of time they will control vegetative growth. Permanent control seldom extends beyond the fourth or fifth year, although growth-retarding effects may be noticeable for several years after that time.

Sterilants readily soluble in water, such as ordinary salt (sodium chloride), sodium chlorate, ammonium sulfamate, and ammonium thiocyanate, as well as some of the relatively soluble arsenicals, are frequently applied as a spray, with standard spraying equipment. Sterilants which are insoluble, or relatively so, such as arsenic trioxide and borax, are ap-

plied dry, either by hand or with a mechanical spreader. Ordinary fertilizer distributors or lime spreaders are sometimes used. Frequently, the weed growth is cut off level with the ground and the sterilant applied to the bare surface, for maximum effectiveness. Amounts applied may vary as much as 300 to 1500 pounds per acre.



This spreader is a two-wheeled hand cart with a small hopper or trough to hold the sterilant. The dispensing mechanism can be a brush or paddle system extending the width of the hopper, which

feeds material through holes in the bottom of the hopper as the brush or paddle revolve. A sliding double bottom with holes to match the hopper bottom can be used for metering and to shut off flow.

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